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SOIL REFERENCE BOOKLET FOR THE PLANE CREEK DISTRICT

Soil-specific Nutrient Management Guidelines for Sugarcane Production in the Plane Creek District

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By

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Dr Andrew Wood is Productivity Manager with Sucrogen in the Herbert River district. Andrew has 30 years' experience in the industry. Apart from a good general knowledge of sugarcane production, he has been largely responsible for mapping soils in the Herbert sugarcane district at a scale of 1:5000. This is unparalleled in any other sugarcane growing region in Australia. Andrew has led a number of projects covering aspects of sugarcane production which were funded by various organisations (SRDC, CRC Sugar, Envirofund and NHT). He is the author / co-author of a large number of scientific papers, books and reports.

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Dr Barry Salter is a Senior Research Agronomist with BSES Limited Central Experiment Station at Mackay. He has worked in the sugar industry for approximately 10 years. As a PhD student with the CRC for Sustainable Sugar Production he investigated sucker development in the Wet Tropics. Barry was a member of the Sugar Yield Decline Joint Venture which developed the 'new farming system' which incorporates minimum tillage, legume fallows and controlled-traffic. Apart from his current R&D role in investigating row-spacing and variety interactions, and biomass accumulation within the Cane-2-Fuel project. He continues to be involved in projects aimed at ensuring sustainable nutrient management in sugarcane production.

Dr Phil Moody is a Principal Scientist and Group Leader with the Queensland Department of Environment and Resource Management at Dutton Park, Brisbane. He is a well respected soil scientist with special skills and knowledge in soil chemistry. In particular his research initiatives have included substantial work on soil phosphorus and organic carbon. During the last 25 years Phil has been the author / co-author of a large number of scientific papers and reports. Apart from his work with sugarcane nutrition, he is involved in various international projects, particularly in south-east Asia.

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GLOSSARY OF TECHNICAL TERMS

It is inevitable that specialist and technical words have to be used in this publication. To assist those not familiar with some of these words, we have included a list of technical terms. This can be used as a reference source whilst reading the book.

Acidic cations: Positively charged ions of aluminium and hydrogen that give the soil CEC an acid reaction. Aluminium and hydrogen are always present in large quantities in the soil but they are only present on the CEC and in the soil solution if the soil pH is below 5.5.

Acid saturation: The proportion of the soil CEC occupied by the acidic cations aluminium and hydrogen. It appears on soil tests as aluminium saturation. Low acid saturation is desirable so that more of the CEC is available for storing nutrient cations.

Acid sulphate soils: Extremely acidic soils with high levels of S caused by oxidation of iron compounds in the subsoil. These soils become problematic when they are exposed to air by construction of drains or other earth work operations. Under such conditions the sulphide components of the iron compounds are converted to sulphuric acid.

Alluvial: Soils derived from recent stream deposits. These soils dominate floodplains.

Ameliorant: A substance added to soil that slowly improves its nutrient status and physical properties, usually beyond a single crop cycle. Examples are gypsum, lime and mill by-products.

Amino nitrogen: A form of nitrogen found in sugarcane juice that can increase colour in sugar. It is caused by excessive amounts of nitrogen available from the soil or from fertiliser.

Anions: Negatively charged ions such as nitrate, phosphate and sulphate.

Cations: Positively charged ions that are held on to the negatively charged sites on the soil CEC. The major cations are calcium, potassium, magnesium, sodium and ammonium.

CEC (Cation Exchange Capacity): A measure of a soil's capacity to store and exchange cations. The value of the CEC is dependent on the amount and type of clay and on the amount of humus. CEC is expressed as milli-equivalents per 100 grams of soil (me%) or as centimoles of positive charge per kg of soil (cmol(+)/kg).

Clay minerals: The basic building blocks of clay. They are formed from the weathered minerals in rocks and include aluminium and silicate layers as well as oxides and hydroxides. (A mineral is a naturally occurring substance that has a definite chemical composition and an ordered structure).

Colour: Soil colour refers to the colour of the soil when it is moist. A simple system using everyday terms is used in this booklet. Soil scientists use a more complicated system in which the colour is matched to a series of standard colours (Munsell Soil Colour Chart).

Colluvial deposits: Sediment accumulated on gentler slopes at the base of hills which has moved downslope.

Compaction: A reduction in pore space in soil (meaning less air space and poorer infiltration rates) caused by machinery traffic and inappropriate tillage.

Critical level: The value for a nutrient in either a soil or leaf test above which a yield response is unlikely to occur when that nutrient is applied.

Decomposition: The breakdown of a complex substance to something simpler. The process can be caused by weathering, chemical change (increased acidification) or biological action.

Deficiency: A nutrient level below the critical level. In extreme cases a deficiency is reflected by plant symptoms such as leaf colour or poor growth.

Denitrification: The conversion of the nitrate form of nitrogen to a gas. It occurs under waterlogged conditions in the presence of organic matter and suitable bacteria.

Dispersive soil: A dispersive soil usually has a high ESP which causes the soil particles to separate from each other with a resulting breakdown of soil structure.

District yield potential: This is determined from the best possible yield averaged over all soil types within a district. It is defined as the estimated highest average annual district yield (tonnes cane/hectare) multiplied by a factor of 1.2. This enables recognition of differences in the ability of districts to produce cane. The district yield potential for Plane Creek is 120 t cane / ha / year.

DTPA: Chemical used in soil analysis to extract micronutrients from the soil.

Duplex soil: It describes a soil where there is a sharp texture contrast between the A and B horizons. A duplex soil is often characterised by a sandy or loamy surface horizon with a clear change to a clay subsoil.

Exchangeable nutrients: Essential nutrients (calcium, potassium, magnesium and sodium) present as cations associated with the soil CEC. They have the ability to exchange easily with each other.

Exchangeable Sodium Percentage (ESP): The percentage of the CEC occupied by sodium. ESP in the topsoil of more than 5% is undesirable as it causes soil structure to break down.

Flocculation: The grouping of clay particles which is an essential pre-requisite for the formation of good soil structure.

Horizon: A layer of soil roughly parallel to the land surface which is distinct from the layers above and/or below it. Differences are based on colour, texture, structure or some other property. Surface horizons are often not apparent in agricultural soils because they have been mixed by tillage operations.

Humus: Stabilised soil organic matter distinct from decomposing trash.

Jarosite: A pale yellow potassium iron sulphate mineral (main weathering product of pyrite oxidation) in acid sulphate soils.

Leaching: The downward movement of water through the soil and the accompanied movement of soluble nutrients and suspended clay particles.

Massive structure: A soil with no apparent structure. Such soils are very lumpy, difficult to cultivate and set hard when dry.

Micronutrient: An essential nutrient that is required in very small quantities, <10 kg/ha/year, such as copper and zinc.

Mineralisation: The breakdown of humus (stabilised organic matter) and release of nutrients especially nitrate, ammonium, sulphate and phosphate.

Mottles: Patches of lighter or darker colour in soils often indicating the effects of poor drainage.

New land: Land in its first crop cycle of sugarcane.

Nitric K: Potassium extracted with the use of strong nitric acid. It is a crude measure of the potassium reserve in the clay minerals.

Organic matter: Carbon in the soil derived from plant matter. It is composed of carbon, hydrogen and oxygen, but also contains nitrogen, phosphorus and sulphur. In this booklet organic matter is measured as organic carbon (org C) using the Walkley-Black procedure.

Parent material: The material (rock or alluvium) from which soils have formed.

Peds: Aggregates of soil particles, usually only found in undisturbed soil.

Permeability: The ability of soil to drain water through the profile. It is dependent on pore space which is reduced by compaction.

pH: The scale that is used to measure acidity and alkalinity. A pH of 7 is neutral, less than 7 is acidic, greater than 7 is alkaline. In this booklet soil pH is the pH in a 1:5 soil: water suspension.

Plant Available Water Capacity (PAWC): The amount of water in the soil profile within the rooting zone between field capacity (full) and permanent wilting point (dry).

P sorption: The process by which phosphorus is held tightly onto soil particle surfaces and rendered relatively unavailable to plant uptake.

Pyrite: An iron sulphide mineral often found in tidal swamps and brackish sediments. If submerged, these minerals are relatively harmless. However, when exposed through falling water levels, the pyrite will oxidise to jarosite which forms highly acidifying acid sulphate soil.

Readily Available Water (RAW): The amount of soil water within the rooting zone that can be easily accessed for plant growth. Irrigation management should aim to maintain soil moisture levels in the "readily available" range.

Sodic soil: Soils having high exchangeable sodium levels (see ESP). Such soils have a poor structure, disperse easily and are prone to erosion.

Soil profile: A vertical section through the soil showing the arrangement of soil horizons.

Soil structure: The arrangement of soil particles into aggregates (peds) and the pore spaces between them.

Soil texture: A property that depends on the relative proportions of coarse sand (2 - 0.2 mm), fine sand (0.2 - 0.02 mm), silt (0.02 - 0.002 mm) and clay (< 0.002 mm) but may be modified by organic matter or type of clay minerals.

Subsoil: Soil below the cultivated zone commonly sampled at 40 - 60 cm depth.

Topography: The shape of the landscape including height of hills, general slope and position of drainage lines.

Topsoil: The cultivated zone of soil commonly sampled at 0-20 cm depth.

Toxicity: A high level of nutrient that causes plant injury and/or reduction in growth.

Volatilisation: The loss of ammonia gas from soil, mainly associated with urea applied to the soil or trash surface.

Water holding capacity: The amount of water a soil can hold after drainage.

Waterlogging: The saturation of soil with water so that all air is excluded (anaerobic). Under these conditions denitrification can occur.

Weathering: The decomposition of minerals into different sized particles caused by carbon dioxide, water and biological processes.

INTRODUCTION

From 2003 to 2007, soil reference booklets entitled *Soil-Specific Management Guidelines for Sugarcane Production* were produced for cane growers in the Herbert, Proserpine, Johnstone and Bundaberg districts respectively. Those booklets described the basic principles of soil management and presented nutrient guidelines for a range of soils. In a similar manner this booklet is aimed at soil-specific nutrient management in the Plane Creek district. It is based on research conducted in the area as part of a project partially funded by SRDC - BSS232 Improved Nutrient Management in the Australian sugarcane industry.

Our philosophy is that knowledge of soils should form the basis for making management decisions on-farm. Not only does soil type influence decisions on which variety to plant and how much fertiliser to apply, but it also has an impact on the choice of tillage practices, planting techniques, drainage and irrigation requirements, and harvest scheduling. A major objective of this publication is to help growers integrate their knowledge of different soils. This includes the appearance of soils, their occurrence in the landscape, their properties and how they should be managed. Soil-specific guidelines as presented in this booklet represent a much more precise way of managing fertiliser inputs than the traditional 'one size fits all' approach. It provides a benchmark against which soils and soil analyses can be compared. However, it is not intended as a substitute for on-farm soil and leaf testing. Ideally each block on the farm should be sampled every crop cycle for both soil and leaf analyses. A system of record keeping should also be implemented which records nutrient inputs, changes in soil fertility, and crop productivity and profitability.

This philosophy is particularly appropriate for the current circumstances in the Australian sugarcane industry. The escalating costs of fertiliser, the need to reduce production costs and mounting environmental pressures demand responsible soil and nutrient management. The guidelines in this booklet are aimed at providing best-practice soil and nutrient management for Plane Creek cane growers. Use of these will not only maintain or improve crop yields and soil fertility, but will also provide opportunities for cost reductions whilst enhancing sustainability and delivering positive environmental outcomes by minimising possible off-site nutrient movement.

CHAPTER 1

Introduction to Plane Creek soils and their properties

Sugarcane in the Plane Creek area is grown on a wide variety of soils. The range of soil properties is caused by factors such as climate, parent material, topography and the action of organisms. The rock types in the catchment influence the mineralogy and nutrient status of soils and clays that form by weathering. Through processes of erosion and sediment transport, soil material gradually moves down slope and into streams and rivers where it is mixed. During flood events, sediment is deposited on floodplains. Thus the geological composition of the various catchments in the Plane Creek district has a major bearing on the type of soils that form in different parts of the landscape. Time is also a critical component of soil formation. Knowledge of how the different soils have formed is important in understanding their fertility, chemical and physical properties, and reactions between soils and fertilisers.

Soil formation and distribution

The Plane Creek area can be divided into four broad landform units based on their geological history (Wills and Baker,1988). These are:

1. The sub-coastal mountains
2. Discontinuous coastal ranges
3. Coastal plains
4. Enclosed alluvial plains

The **sub-coastal mountains** form the watershed between streams flowing to the coast and those flowing away from the coast. They reach their highest point at Black Mountain (685 m) west of Koumala. They are formed mainly of acid to intermediate igneous rocks and occur as steep upland areas with shallow soils and smaller areas of gentler slopes with colluvial deposits.

The **discontinuous coastal ranges** occupy a large area to the north of Sarina, a smaller area east of Koumala and a narrow strip immediately west of the Bruce Highway to the north and south of Carmila. They are formed mainly of intermediate and basic volcanic rocks interbedded with marine sediments and include steeper areas with shallow soils and undulating low hills with deeper soils, particularly where there are colluvial deposits.

The **coastal plains** occupy a large area south of Sarina and east of the main highway. A small area also occurs north-west of Sarina, on the eastern side of Alligator Creek. It is thought that marine rather than fluvial processes have influenced the development of these landforms as existing streams have cut down steeply through the plain and fragments of coral and calcareous nodules occur at depths of 1-2 m.

The **enclosed alluvial plains** occur along some of the coastal streams and contain recent alluvial deposits.

Position in the landscape

Because of the interactive effect of the soil-forming factors, the existence of soils with specific characteristics is predictable in the landscape. Soils differ according to their position in the landscape and due to the interaction between topography, geology and climate. For example, a typical sequence of soils north of Sarina consists of shallow, stony brown soils on the upper slopes of the coastal ranges, brown duplex soils on the gentler slopes below and deep black cracking clays in the depressions. Another sequence around Koumala consists of grey brown duplex soils on crests, light grey duplex soils on the gentle slopes below and dark brown, sandy alluvial soils on river terraces and floodplains.

Soil field properties

In recognising the existence of a range of soil types, it is possible to classify them according to complex scientific systems. However, recognition of basic soil field properties such as colour, texture, structure, depth and position in the landscape enables the separation of soils into 'user-friendly' soil types. Soil type used in combination with soil chemical properties (from soil tests) will enable growers and their advisers to make informed decisions about appropriate nutrient management strategies on-farm.

Colour

The colour of soil is determined by the amount of organic matter present, iron oxide levels and the degree of aeration / moisture content. Dark coloured soils have more organic matter than lighter-coloured soils. Well-drained soils have red or brown colours whereas poorer drainage is indicated by paler colours ranging from yellow, grading through to grey, light grey and even blue in very poorly drained soils. Bleached horizons (containing little organic matter or iron) with mottles are indicative of seasonal saturation and intense leaching. The mottles form around larger soil pores and root channels where there is some oxygen. The colours referred to in this booklet relate to soils that are moist.

Soil texture

This is an important soil property as it affects soil structure (see below), the capacity of soil to hold air and water, the amount and availability of nutrients, and many chemical properties. Management issues such as workability, trafficability, erodibility and root development are also associated with soil texture.

Soil texture is a measure of the relative proportions of different sized soil particles. Whilst the largest particles include gravel and sand, the smallest particles are referred to as clay. Silt particles are moderate in size. Soils are classified as sand, loam or clay depending on the proportions of these three basic components. Clay particles, with their large surface area and negative charge, are the most reactive constituents of the soil. They give soils the ability to store positively charged nutrients such as potassium, sodium, calcium and magnesium. The fine pores between the clay particles also allow them to store large volumes of water. Actual texture (particle size distribution) can be determined in the laboratory. Alternatively, soil texture can be estimated in the field using the guidelines provided in Appendix 1.

Structure

Structure is the natural aggregation of soil particles (sand, silt and clay) and organic matter into units called aggregates (peds). Aggregates can differ markedly in terms of size, shape and level of stability. Their presence in soil affects the way soils behave, the growth of plants and the manner in which we manage the soil. For instance, while some structure is essential to enable soil stability and good water-holding characteristics, large and strong structural units in the soil can prevent root penetration and negatively affect tillage operations.

Soil horizons

Soils develop different horizons or layers in their vertical sections. Horizon development varies with the type of soil parent material, organic matter, and the influence of water through leaching or waterlogging. Each horizon has characteristics which relate to soil colour, texture and structure that distinguish it from the horizons above and below it. Farming activities mix together the surface horizons, which we refer to as topsoil. Material below the zone of soil disturbance is referred to as subsoil. In Plane Creek sugarcane producing soils, the top 20 cm is generally considered mixed topsoil whilst soil samples taken from the 40-60 cm depth increment are usually well within the subsoil.

Chemical properties

Clay particles and soil organic matter are largely responsible for the chemical properties of soils due to their reactivity and their small particle size which results in a large surface area.

Cation Exchange Capacity

Cation Exchange Capacity (CEC) refers to the amount of negative charge on clay and organic matter particles that attracts positively charged chemicals called cations. The most common cations in soil are calcium (Ca), magnesium (Mg), potassium (K), sodium (Na) and aluminium (Al). As these cations are held electrostatically on soil particles, they are not easily leached but can be exchanged for other cations, thus enabling plants to have access to them. Soils in the wetter tropical areas generally have a lower CEC than soils in cooler or drier areas as they are more highly weathered. As soils become more acid due to ongoing leaching, their CEC is further reduced. The CEC of soils in this booklet is defined as the Effective Cation Exchange Capacity (ECEC). This is the sum of the exchangeable cations (K^+, Ca^{2+}, Mg^{2+}, Na^+, Al^{3+} and H^+) as measured in the laboratory. The ECEC is classified as very low (less than 2 me%), low (2- 4 me%), medium (4 - 8 me%) or high (more than 8 me%).

Organic matter

Soil organic matter is derived from the breakdown of plant and animal matter. It also has the ability to attract nutrients and has a greater cation exchange capacity than a similar mass of clay. Dark colour and good structure are indicators of high organic matter. Soils in the Plane Creek district have topsoil organic C contents between 0.4% and 1.8%. Organic matter, measured as organic carbon %, improves soil structure and is a source of nitrogen (N), phosphorus (P), sulphur (S) and trace elements. There is no optimum level of organic matter, but it is best to maintain it at the highest possible level. The organic matter content of a soil is determined by the balance between inputs of organic material and the breakdown (mineralisation) of the existing stabilised soil organic matter (humus). Green harvested sugarcane inputs about 10-15 t/ha in trash and 3 t/ha in roots per year, but 80% percent of this is lost by decomposition in the first year. In soils with low clay content, organic matter is the chief store for exchangeable cations. Organic matter is a major source of N which is released by mineralisation (the process in which organic matter is broken down into its mineral components). The potential amount of N released from specific soils can be estimated using an N mineralisation index. This index is used to guide nitrogen fertiliser recommendations.

Building organic matter levels is difficult in tropical soils due to rapid decomposition rates. Breakdown of organic matter is enhanced by cultivation. Trash conservation following green cane harvesting and the use of fallow green manure crops are the major ways organic matter can be added to soil in sugarcane farming systems. Other methods of maintaining soil organic matter include reducing or eliminating tillage operations, preventing soil erosion and use of imported organic matter sources such as mill mud, mud / ash and composted products.

Acidity and soil pH

Acidity in soils is caused by excessive hydrogen (H) and aluminium (Al) ions on the cation exchange sites. Acidity is expressed in terms of pH: pH values less than 7 are acidic whilst those more than 7 are alkaline. Soil tests commonly include two measures of acidity: pH in water (pH_{water}) and pH in calcium chloride solution (pH_{CaCl2}). In this booklet we only consider pH in water. Soil pH values greater than 5.5 are desirable for plant growth in the Plane Creek district. Under acidic conditions, Al is present in its soluble form and is toxic to most plants. Fortunately, Australian sugarcane varieties are fairly tolerant to high levels of Al. However, this does not apply to legume crops which may be grown as fallow crops. Regular additions of lime are essential particularly if legume crops are going to be part of a farming system on acidic soils. Increased acidity (lower pH) is associated with reduced availability of N, P and S, but greater availability of micro-nutrients such as copper (Cu) and zinc (Zn).

Low pH may reduce the CEC of some soils and causes the soil CEC to be dominated by the acidic cations H^+ and Al^{3+}. This reduces the storage capacity for nutrients such as Ca, Mg and K and can be critical particularly on sandy soils with low CEC. Soil acidification is a natural process which is accelerated by the leaching of nitrate from nitrogen fertilisers and the removal of cane to the mill. Regular use of liming materials will reduce soil acidity, neutralise applied acidity arising from nitrogen fertiliser use and replace Ca and Mg (if using Mag lime or dolomite) withdrawn in the harvested crop.

Flocculation

Clay particles can remain suspended in water or they can flocculate and settle. Soils with their CEC dominated by calcium, magnesium and aluminium ions flocculate well and do not disperse easily in water. However, sodium dominated soils with an exchangeable sodium percentage (ESP) greater than 5% are unstable when wet and disperse. Clays that disperse readily fill-up pore spaces and reduce permeability to both air and water.

Sodicity and salinity

Sodic subsoils restrict rooting depth, reduce soil water availability to roots and may increase susceptibility to surface erosion. Salinity is an issue for sugarcane grown on coastal and marine plains, and inland areas where water tables are above 0.5 m causing salt accumulation in mid and lower landscape positions.

Plant nutrition

Plants require 16 elements for optimum growth. Carbon (C), hydrogen (H) and oxygen (O) are supplied from air and water. The other mineral elements can be divided into three groups: macronutrients (nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulphur (S) and magnesium (Mg)) which are required in relatively large amounts (20 - 200 kg/ha); micronutrients (iron (Fe), copper (Cu), zinc (Zn), molybdenum (Mo), manganese (Mn), boron (B), and for some plants sodium (Na)) which are required in small amounts (less than 10 kg/ha/crop). Silicon (Si), which is considered beneficial for plant growth, is required in fairly large quantities. All of these nutrients are naturally available in soils. Some soils can supply more of a particular nutrient than other soils. Fertilisers and soil ameliorants are used to supplement these supplies of nutrients and prevent the mining of nutrients stored in our soils.

Nitrogen (N)

Past research suggests that a crop of sugarcane requires about 1.4 kg N /tonne cane up to 100 tonnes cane/ha and 1.0 kg N/ha thereafter. In order to achieve sustainable crop production, maximum use must be made of all the available N sources within the N cycle (Figure 1.1). To do this it is important to have an understanding of the transformations of N from one form to another.

Mineralisation of organic matter to ammonium and nitrate is on-going and the amount released depends on the amount of organic matter and microbial activity. The rate of mineralisation is also dependent on temperature and moisture and will therefore vary through the year according to climatic conditions. However, irrespective of the actual rate of mineralisation, this N is available for plant uptake and should be taken into account when nitrogen requirements are calculated. Nitrate levels fluctuate considerably in the soil. They rise substantially after cultivation in some soils (those high in organic matter) and after fertilisation. They are reduced by crop removal and after heavy rainfall (by leaching and run-off) and waterlogging (denitrification). Ammonium-N is subject to volatilisation, a loss often associated with urea applied to the surface of a trash blanket. More detail is provided on these processes in Figure 1.1.

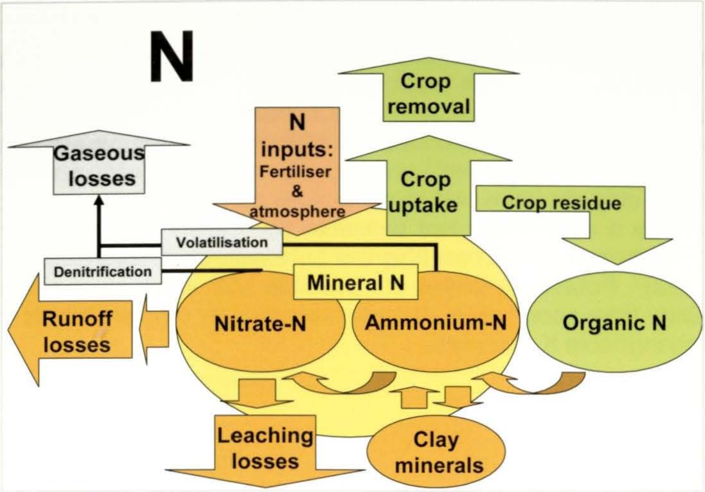


Figure 1.1 Schematic diagram of the nitrogen cycle

As it is important to minimise nitrogen losses, the following strategies are suggested:

- Apply nitrogen according to the specific requirements of different soils based on their N mineralisation index (as shown in Chapter 2).
- Reduce nitrogen losses from leaching, run-off and denitrification by splitting applications of nitrogen and avoiding applications just before the wet season.
- Reduce the potential for denitrification by improving drainage and placing fertiliser on the cane row where waterlogging is less likely.
- Reduce the potential for ammonia volatilisation when urea is applied to the surface of a trash blanket by delaying application until a cane canopy has developed. Applying the urea below the soil surface removes the possibility of losses by volatilisation but could increase the risk of loss by denitrification if waterlogging occurs.

Phosphorus (P)

Phosphorus cycles between the various forms of P in soil (Figure 1.2), with some forms being more readily available than others. In some soils with high clay and / or organic matter content, phosphorus is held tightly onto soil particle surfaces by a process called P sorption. More P fertiliser needs to be applied when P is strongly 'sorbed' as this P is relatively unavailable to plants. A new soil test, known as the Phosphorus Buffer Index (PBI), is now available to measure how strongly different soils sorb added phosphorus.

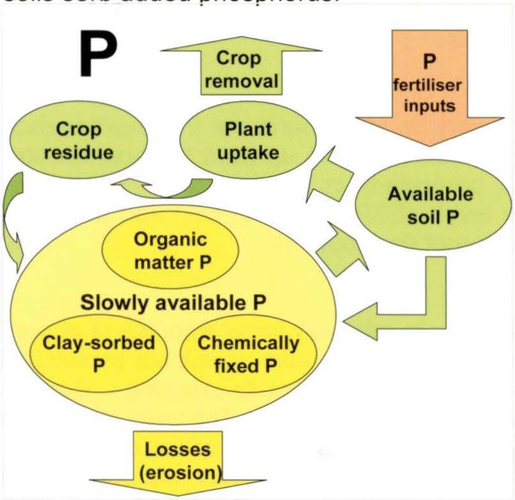


Figure 1.2 Soil phosphorus cycle

Potassium (K)
Sugarcane needs potassium in large quantities mainly for the maintenance of water balance. On average 150 kg K/ha is removed each year in the cane harvested and sent to the mill. Plants luxury feed on potassium where surplus is available. Potassium is present in a number of distinct forms within soils. A schematic diagram of the potassium cycle is shown in Figure 1.3.

Lattice K is part of the clay structure and in some soils can represent a major part of the total K in the soil and provide a source of plant available K. Slowly available non-exchangeable K exists in some K minerals and this can also act as a source of exchangeable and solution K (plant available forms). Potassium losses are possible with leaching of exchangeable and soil solution K, particularly from sandy soils. It can also occur by erosion, which results in losses of lattice and non-exchangeable K reserves.

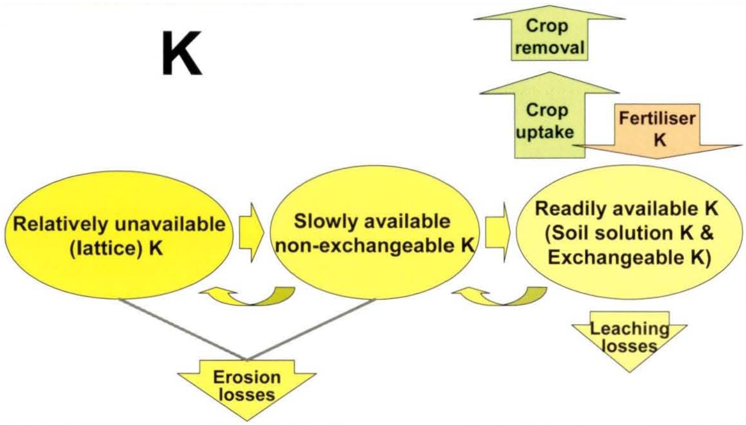


Figure 1.3 Soil potassium cycle

Calcium (Ca)
Calcium is essential for cane growth and for cell wall development. It is taken up as a positively charged cation from the soil solution. Soil reserves of Ca, which are held on the CEC, are supplemented by additions of liming materials and by gypsum. A cane crop removes about 30 kg Ca/ha/year but when applying lime, considerably more Ca than this is applied because of the need to control soil acidity.

Magnesium (Mg)
Magnesium is essential for plant photosynthesis, as it is the main mineral constituent of chlorophyll. Like calcium, it is taken up from the soil solution and from the CEC, and total uptake is similar to calcium.

Sodium (Na)
Sodium is required in very small amounts for the maintenance of plant water balance. It is stored on the CEC and can be taken up from the soil solution by plants. Sodium is readily supplied from rainfall, particularly in coastal areas. It can have a detrimental effect on soil structure even at low levels (ESP of around 5%) and at higher levels (ESP above 15%) can restrict plant growth and root development.

Sulphur (S)
Sugarcane requires sulphur in relatively large amounts of about 25 kg S/ha/year, which is used for plant structure and growth. Plants take up sulphur as sulphate which is more mobile in soils than phosphate and is therefore subject to leaching. Consequently fertilising may need to supply more than that harvested in the crop. The main store of sulphur in soils is organic matter. The release of sulphur from the mineralisation of soil organic matter should be allowed for when developing fertiliser recommendations. Other natural sources of sulphur are rainfall and irrigation.

Micronutrients

Micronutrients are taken up by cane in much smaller quantities than the nutrients already mentioned and are generally regulators of plant growth. Both copper (Cu) and zinc (Zn) have been shown to be deficient in some Plane Creek soils, particularly low organic matter sandy soils, whereas iron (Fe) and manganese (Mn) are usually well supplied. Little is known about the status of molybdenum (Mo) and boron (B) in Plane Creek soils.

Silicon (Si)

Deficiencies of silicon (Si) have been detected in the Plane Creek area and occur on very sandy soils.

CHAPTER 2

Principles for determining nutrient management guidelines

When developing nutrient management guidelines for the different soil types in the Plane Creek district, the following factors were taken into account:

- Crop yield potential
- Nutrients removed in the harvested crop
- Nutrients returned to the soil in trash, fallow crops and mill by-products
- Nutrients released by the mineralisation of soil organic matter
- Nutrients released by the weathering of soil minerals
- Nutrients fixed (held tightly) on soil particle surfaces
- Soil acidity
- Critical levels of nutrients as determined by soil analysis
- The balance and interactions of different nutrients, particularly those on the soil CEC
- The risk of nutrient loss processes occurring

A wide range of soil physical and chemical properties were used to assist this process. These data were obtained from the analysis of samples taken from the soil reference sites and from the analysis of soil samples from growers' farms in the Plane Creek district.

They were used to produce the bar graphs for each soil type in Chapter 3 and include:

- Soil particle size distribution, particularly clay % (soil texture)
- Soil organic carbon % (a measure of organic matter)
- Nitrogen mineralisation index (a measure of the amount of N released from the breakdown of soil organic matter)
- Soil pH (a measure of soil acidity)
- Cation Exchange Capacity (CEC)
- Exchangeable K, Ca, Mg and Na (cations held on the soil CEC)
- Nitric K (a crude measure of K reserves)
- Exchangeable Sodium Percentage or ESP (the % of the CEC occupied by sodium)
- Exchange acidity (a measure of acidic cations held on the CEC)
- Acid saturation (% of the CEC occupied by acidic cations)
- BSES and Colwell P (indices of available phosphorus)
- Phosphorus Buffer Index - PBI (a measure of the degree to which added P is held tightly onto soil particle surfaces and is unavailable for plant uptake)
- Sulphur, copper and zinc

Nitrogen (see Wood and others, 2003; Schroeder and others, 2006)
Nitrogen guidelines are based on a combination of **district yield potential** and **soil N mineralisation index**. The district yield potential is determined from the best possible yield averaged over all soil types within a district and is defined as the estimated highest average annual district cane yield (tonnes cane/ha) multiplied by a factor of 1.2. The district yield potential for Plane Creek is 120 tonnes cane/ha (estimated highest average annual yield of 100 tonnes cane/ha multiplied by 1.2). This concept of district yield potential recognises differences in the ability of districts and regions to produce cane. For example, the Burdekin region with its fertile soils, higher temperatures and access to water, has a higher yield potential than other districts.

The district yield potential is used to establish the base N application rate according to an estimate, previously developed by CSIRO scientists. Accordingly, 1.4 kg N per tonne of cane is required up to a cane yield of 100 tonnes/ha and 1 kg N per tonne/ha thereafter. With the new approach however, inputs are adjusted according to the N mineralisation index, which is based on soil organic carbon (%) and is related to soil colour. Generally the darker the soil, the more organic matter is present. Seven N mineralisation index classes are recognised (very low, low, moderately low, moderate, moderately high, high and very high). With the district yield potential for the Plane Creek district set at 120 tonnes cane/hectare, the baseline N application rate is 160 kg N/ha. Adjustment to take account of the contribution of N from the soil organic matter (according to the N mineralisation index) results in a set of guidelines for N fertiliser inputs as shown in Table 2.1.

If a sub-district or farm **consistently** produces higher yields than the district yield potential, the baseline N application rate should be adjusted upward by 1 kg N per tonne of cane above the district yield potential. For example, if the average yield on a farm in the Plane Creek district, calculated over a ten year period, is 130 tonnes cane/hectare, then the baseline N application rate should be set at 170 kg N/ha. The N application rates based on the soil organic carbon would then be 10 kg N/ha greater than those shown in Table 2.1. The N application rates for replant or ratoon cane, in this case, would be 170 kg N/ha for soils with organic carbon content of < 0.4%. Where the organic carbon content exceeded 2.4%, the appropriate N application rate would be 110 kg N/ha. Conversely, if a sub-district or farm **consistently** produces lower yields than the district yield potential, the baseline N application rate should be decreased using the same approach.

Table 2.1 - N mineralisation index and suggested nitrogen rates for replant and ratoon crops (see Schroeder and Wood, 2001)

N mineralisation index	Organic Carbon %	Suggested N rate for replant and ratoons
VL	<0.4	160
L	0.4 - 0.8	150
ML	0.8 - 1.2	140
M	1.2 - 1.6	130
MH	1.6 - 2.0	120
H	2.0 - 2.4	110
VH	>2.4	100

After determining the appropriate N application rate in this way, further discounting is required to recognise the contributions of other sources of N. These sources include N from legume fallow crops, harvested legume crops, application of mill by-products and nitrogen remaining in soil after small crop production.

Determining N application rates for sugarcane following legume fallows (see Bell and others, 2003; Garside and Bell, 2001)

Unlike N held in soil organic matter, legume N is readily available for plant uptake and should be treated the same way as fertiliser nitrogen for the purposes of calculating nitrogen requirement. Information published by scientists working in the Sugar Yield Decline Joint Venture has provided details on how to estimate the amount of legume N being returned to the soil from a legume crop. The amount of N available to the succeeding sugarcane crop will be dependent on the type of legume, how well it was grown, whether it is well-nodulated and has fixed atmospheric N and whether the 'grain' was harvested. A summary of the calculations for various legume fallows is shown in Table 2.2. This information can then be used to adjust the amount of nitrogen fertiliser required for the different soils following different legume fallows. The values shown in **BOLD** in Table 2.2 are used as examples in Table 2.3.

Table 2.2 - **Calculation of N contribution from well-nodulated fallow legume crops as supplied by the Sugar Yield Decline Joint Venture** (see Schroeder and others, 2005)

Legume crop	Fallow crop dry mass (t/ha)	N (%)	Total N contribution (kg N/ha)	N contribution if grain harvested (kg/ha)
Soybean	8	3.5	360	120
	6		**270**	**90**
	4		180	60
	2		90	30
Peanut*	8	3	n/a	125
	6			100
	4			65
	2			25
Cowpea	8	2.8	290	100
	6		220	75
	4		145	50
	2		**70**	25
Lablab	8	2.3	240	80
	6		180	60
	4		120	40
	2		60	20

Table 2.3 - **Effect of fallow management on N requirement** (see Schroeder and others, 2005)

Crop	N mineralisation index						
	VL	L	ML	M	MH	H	VH
Replant cane and ratoon after replant	160	150	140	130	120	110	100
Plant cane after a grass/bare fallow	140	130	120	110	100	90	80
Plant cane after a poor legume crop (e.g. 2 t/ha cowpea green manure: N rate minus **70** kg N/ha)	90	80	70	60	50	40	30
Plant cane after a good legume crop (e.g. 6 t/ha soybean: N rate minus **270** kg N/ha)	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Plant cane after a good legume crop harvested for grain (e.g.6 t/ha soybean: N rate minus **90** kg N/ha)	70	60	50	40	30	20	10
First ratoon after a good legume crop*	160	150	140	130	120	110	100
Second ratoon after a good soybean/cowpea crop	160	150	140	130	120	110	100

* Data from the Sugar Yield Decline Joint Venture and BSES trials suggest that N applied to the first ratoon sugarcane crop after a good legume crop can possibly be reduced. The reduction will depend on several factors which include legume residue management, soil type, climate and tillage practices.

Modifying N application rates for sugarcane where mill by-products have been used

The amount of N applied needs to be discounted for up to 3 years after application of mill by-products. The amount of N to be subtracted from N application rates following the use of mud/ash mixture is as follows:

Product	Application rate	To be subtracted from the appropriate N application rate		
		Plant crop	First ratoon	Second ratoon
Mud/Ash	100-150 wet t/ha	50 kg N/ha	20 kg N/ha	10 kg N/ha

Phosphorus

Two techniques are used to decide how much P fertiliser is required. Firstly a BSES critical level is used to determine the quantity of P fertiliser required. This is then modified by the soil's ability to fix added P (P sorption), which determines how much of the fertiliser P will be available to the crop. The P sorption class of each soil is based on the Phosphorus Buffer Index (PBI) which is measured in the laboratory (Table 2.4). It can also be estimated from the clay % and organic matter content of a particular soil (Table 2.5).

Table 2.4 - P sorption classes based on PBI (see Burkitt and others, 2000)

P sorption class	PBI
Low	< 140
Moderate	140 - 280
High	281 - 420
Very high	> 420

Table 2.5 - P sorption classes based on Org C (%) and texture class
(see Wood and others, 2003)

% Org C	**Sand** (<24% clay)	**Loam** (24-36% clay)	**Clay** (>36% clay)
<0.6 %	Low	Low	Moderate
0.6 - 1.2 %	Low	Moderate	Moderate
1.2 - 1.8 %	Moderate	High	High
>1.8%	High	High	High

Clay % is not determined in most soil tests but can be estimated from a soil texture determination. If that is not available then an estimate of texture can be made from the Cation Exchange Capacity of the soil, as shown in Table 2.6.

Table 2.6 - Estimate of soil texture class from CEC

CEC (me%)	Texture class
<4	Sand
4 - 8	Loam
>8	Clay

Currently, some older sugarcane areas do not require any P fertiliser due to their long history of P fertilisation. New land, on the other hand, is often deficient in available P with BSES P values less than 5 and requires P fertiliser in the first crop cycle (Table 2.7). The guidelines in Table 2.7 are based on a combination and subsequent re-interpretation of information supplied by Calcino (1994), Bramley and Wood (2000) and Burkitt and others (2000).

Table 2.7 - **Phosphorus guidelines for old and new land** (see Schroeder and others, 2006)

BSES P in soil test (mg/kg)	P sorption class	Suggested phosphorus application (kg/ha)	
>60	All	Nil P for at least 2 crop cycles	
50 - 60	All	Nil P for 1 crop cycle	
		Plant	Ratoon
40 - 50	Low	20	0
	Moderate	20	5
	High	20	10
30 - 40	Low	20	10
	Moderate	20	15
	High	20	20
20 - 30	Low	20	10
	Moderate	20	20
	High	30	25
10 - 20	Low	30	15
	Moderate	30	20
	High	40	30
5 -10	Low	30	20
	Moderate	40	30
	High	50	40
<5	Low	40	20
	Moderate	60	30
	High	80	40

Discounts should be made where mill by-products have been used as they are a source of P.

Mud/ash mixture (applied at 100-150 wet t/ha)
Apply nil P for at least 1 crop cycles

Potassium

Potassium fertiliser guidelines are based on two measures of soil potassium: readily available or exchangeable K (potassium in the soil solution and on the CEC) and reserve or nitric K (slowly available, non-exchangeable potassium). The maximum recommended K rate for Plane Creek is 120 kg K/ha which is slightly less than the amount of K removed in the harvested sugarcane crop when trash is retained. This upper limit on K applied is to avoid luxury consumption of K by the crop (resulting in reduced juice quality) and leaching losses on low CEC soils. It is justified by the relatively high K reserves on some soils that slowly but continuously become available. Hence, fallow plant requires less K than replant or ratoons.

Soil critical levels for exchangeable K are dependent on clay content and soils are assigned into one of three textural classes: sand (<24% clay); loam (24 - 36% clay); and clay (>36% clay). Potassium fertiliser recommendations can then be derived as shown in Table 2.8.

Table 2.8 - Potassium fertiliser guidelines (see Wood and Schroeder, 2004)

Plant (kg/ha K)						
Nitric K (me%)	Exchangeable K (me%)					
	< 0.20	0.20 - 0.25	0.26 - 0.30	0.31 - 0.35	0.36 - 0.40	> 0.40
< 0.70	100 (sand)	80 (sand)	50 (sand)	50 (sand)	Nil (sand)	Nil
	120 (loam)	100 (loam)	80 (loam)	50 (loam)	Nil (loam)	
	120 (clay)	120 (clay)	100 (clay)	80 (clay)	50 (clay)	
> 0.70	80 (sand)	50 (sand)	Nil (sand)	Nil (sand)	Nil (sand)	
	100 (loam)	80 (loam)	50 (loam)	Nil (loam)	Nil (loam)	
	100 (clay)	100 (clay)	80 (clay)	50 (clay)	Nil (clay)	
Replant & Ratoon (kg/ha K)						
Nitric K (me%)	Exchangeable K (me%)					
	< 0.26	0.26 - 0.30	0.31 - 0.35	0.36 - 0.40	0.41 - 0.45	> 0.45
< 0.70	120 (sand)	100 (sand)	80 (sand)	50 (sand)	Nil (sand)	Nil
	120 (loam)	100 (loam)	100 (loam)	80 (loam)	50 (loam)	
	120 (clay)	100 (clay)	100 (clay)	100 (clay)	80 (clay)	
> 0.70	100 (sand)	80 (sand)	50 (sand)	Nil (sand)	Nil (sand)	
	100 (loam)	100 (loam)	80 (loam)	50 (loam)	Nil (loam)	
	100 (clay)	100 (clay)	100 (clay)	80 (clay)	50 (clay)	

Discounts should be made where mill by-products have been used, because they are sources of K.

Product	Application rate	To be subtracted from the appropriate K application rate	
		Plant crop	First ratoon
Mud/ash	100-150 wet t/ha	120 kg K/ha	Nil

Sulphur

As the mineralisation of soil organic matter is a source of sulphur, S fertilising guidelines are based on the nitrogen mineralisation index. Soils are placed in one of three N mineralisation classes and then soil sulphate critical levels are used to calculate sulphur fertiliser rates (Table 2.9). Discounts should be made where mill by-products have been used, because they supply S.

Table 2.9 - Sulphur fertiliser guidelines (kg S/ha) for plant and ratoon crops

Sulphate S (mg/kg)	N mineralisation index		
	VL - L	ML - M	MH - H
<5	25	20	15
5-10	15	10	5
11-15	10	5	0
>15	0	0	0

Product	Application Rate	To be subtracted from the appropriate S application rate		
		Plant crop	First ratoon	Second ratoon
Mud/Ash	100-150 wet t/ha	10 kg S/ha	10 kg S/ha	nil

Lime (See Aitken, 2000; Nelson, 2001; Wood and others, 2002)
Lime is used to neutralise soil acidity and to supply calcium. Soils are constantly being acidified through the use of nitrogen fertiliser, removal of nutrients in the harvested crop and by leaching of nitrate. Maintenance applications of about 2 tonnes lime/ha each crop cycle are needed to neutralise this effect. The more N fertiliser is used the greater is the lime requirement. In addition, some forms of nitrogen fertiliser acidify more than others (ammonium sulphate acidifies more than urea which acidifies more than calcium ammonium nitrate). Some soil tests include liming estimates to a target pH of 5.5, 6.0 and 6.5. The liming estimate aimed at a soil pH of 5.5 should be used where available, otherwise the guidelines in Table 2.10 can be applied. Lime is recommended when soil pH falls below 5.5 (Table 2.10) and when exchangeable Ca is below the critical value of 1.5 me% (Table 2.11). Discounts are necessary where mill by-products have been used.

Table 2.10 - Lime guidelines for acid soils (when pH_{water} <5.5)

CEC (me%)	Suggested lime application (tonnes/ha)
<2.0	1.25
2.0 - 4.0	2.5
4.0 - 8.0	4
>8.0	5

Table 2.11 - Ag lime guidelines based on exchangeable Ca
(adapted from Calcino and others, 2000)

Ca (me%)	Suggested lime application (tonnes/ha)
> 0.2	3
0.2 - 0.4	2.5
0.4 - 0.6	2
0.6 - 0.8	1.5
0.8 - 1.1	1
1.1 - 1.5	0.5

Mud/ash mixture (applied at 100-150 wet t/ha)
Subtract 1 t/ha Ag Lime from next application

Magnesium

Magnesium guidelines are based on soil critical levels for exchangeable magnesium (Table 2.12). Whilst a magnesium level of 10-20% of CEC is desirable, levels of over 50% of CEC can occur on some soils. This may affect soil physical properties, making the soils prone to hard-setting and possibly causing germination difficulties. However, subsequent growth does not appear to be affected, provided all nutrients are above their critical levels and soil pH is above 5.5.

Table 2.12 - Magnesium guidelines for plant crops (adapted from Calcino, 1994)

Soil test (me% Mg)	<0.05	0.06-0.10	0.11-0.15	0.16-0.20	0.21-0.25	>0.25
Mg rate (kg/ha)	150	125	100	75	50	0

An application of 200 wet t/ha mud/ash mixture is sufficient to supply enough magnesium for one crop cycle.

Sodium

Sodium does not need to be applied to sugarcane but needs to be reduced when the exchangeable sodium percentage (ESP) is above 5% of the CEC in the topsoil. Where this occurs it is suggested that subsoil samples be taken to determine ESP in the soil profile and specialist advice be sought on possible remedial activities. Gypsum is the normal ameliorant for sodic soils because it is relatively soluble even in high pH soils. However lime is an alternative on acidic soils. Rates of application are dependent on exchangeable sodium percentage (ESP). Guidelines are provided in Table 2.13.

Table 2.13 - Gypsum requirement for sodic soils (see Nelson, 2001)

ESP (%)	Gypsum rate (tonnes/ha)
<5	0
5 - 10	2
10 -15	4
>15	6

Micronutrients

Copper and zinc guidelines are based on previously determined soil critical values (Table 2.14). The BSES zinc test is appropriate for acidic soils. The DTPA soil test should be used if soil pH is greater than 6.5. In chapter 3, only DTPA results have been reported. Copper and zinc are most often required on low CEC and very sandy soils. Leaf analysis is also a suitable method of diagnosing whether micronutrient applications are required. Heavy applications of Ag lime may induce deficiencies, particularly of zinc, when micronutrient levels are marginal.

Table 2.14 - Copper and zinc guidelines (see Calcino and others, 2000)

Micronutrient	Soil test value	Suggested application rate
DTPA soil test		
Copper	<0.2 mg Cu/kg	10 kg Cu/ha once per crop cycle
Zinc	<0.3 mg Zn/kg	10 kg Zn/ha once per crop cycle
BSES zinc test		
Zinc	<0.6 mg Zn/kg	10 kg Zn/ha once per crop cycle

Silicon

Two soil tests are appropriate for assessing silicon deficiencies. These are based on calcium chloride extractable Si and dilute sulphuric acid extractable Si. The latter is sometimes referred to as BSES-Si. Ameliorants are only required if both of the Si test values are low (Table 2.15). Leaf analysis is appropriate for assessing whether crops have been able to take up adequate amounts of Si.

Table 2.15 - Silicon guidelines for plant cane
(Calcino and others, 2000; Berthelsen and others, 1999)

	Sulphuric acid (0.005M)		Calcium chloride (0.01M)	Rating	Suggested application rate
Si (mg/kg)	<70	and	<10	Low	Calcium silicate @ 4 t/ha; **or** Cement @ 3t/ha **or** Mill mud/ash @ 100-150 wet t/ha

Description of Plane Creek sugarcane soils and guidelines for their management

This chapter presents information on the location, appearance, properties and management requirements of the main soils used for producing sugarcane in the Plane Creek district. The 33 soil mapping units described in the Plane Creek Sugar Cane Land Suitability Study are shown in Table 3.1.

Table 3.1 - Classification and grouping of Plane Creek soils

Soil parent material is the geological material from which the soils have formed.
The soils described in this booklet appear in bold text.
Page numbers indicate where descriptions of particular soils can be found.

Soil parent material	Soil sub-group	Mapping unit	Great soil group	Australian soil classification	Page
Upland soils derived from acid to intermediate igneous rocks	Coarse textured sedentary soils	Chelona	Lithosol	Rudosol	
		Malin	Gleyed podzolic	Dermosol	
		Marwood	**Gleyed podzolic**	**Grey Chromosol**	**41**
	Medium to fine textured sedentary soils	Urannah	Lithosol	Rudosol	
		Swayneville	Prairie soil	Chromosol	
		Koumala	**Yellow podzolic**	**Chromosol**	**37**
	Medium to fine textured colluvial soils	Borstal	Black earth	Vertosol	
		Shinfield	Solodised Solonetz	Sodosol	
	Coarse textured colluvial soils	Turpad	Siliceous sand	Rudosol	
Upland soils derived from basic to intermediate volcanics	Sedentary soils	Samourgassi	Lithosol	Rudosol	
		Hector	**Prairie soil**	**Brown Dermosol**	**31**
	Colluvial soils	**Cliftonville**	**Yellow podzolic**	**Chromosol**	**27**
		Louisa	Yellow podzolic	Chromosol	
Upland soils derived from acid to intermediate volcanics	Sedentary soils	Breen	Lithosol	Rudosol	
		Moffat	Grey-brown podzolic	Chromosol	
		Saddle	No suitable group	Sodosol	
	Colluvial soils	Freddy	Yellow podzolic	Sodosol	
Soils derived from alluvium	Soils of floodplains, levees and terraces	**Leichhardt**	**Alluvial**	**Rudosol**	**39**
		Hannan	Alluvial	Dermosol	
	Clay soils in areas of poor drainage	**Bell**	**Black Earth**	**Vertosol**	**23**
		Spider	Wiesenboden	Vertosol	
	Duplex soils of alluvial plains	**Gillinbin**	**Soloth**	**Sodosol**	**29**
		Cabbage Tree	Solodised Solonetz	Sodosol	
		Sarina	Solodised Solonetz	Sodosol	
		Turnor	Solodised Solonetz	Sodosol	

Continued on next page

Continued from previous page					
Soil parent material	**Soil sub-group**	**Mapping unit**	**Great soil group**	**Australian soil classification**	**Page**
		Prendergast	Solodised Solonetz	Sodosol	
		Cherry Tree	**Solodised Solonetz**	**Sodosol**	**25**
Soils derived from alluvium	Duplex soils of coastal plains	**Tedlands**	**Solodised Solonetz**	**Sodosol**	**45**
		Sunnyside	**Solodised Solonetz**	**Yellow Sodosol**	**43**
		Alligator	Solodised Solonetz	Sodosol	
		Splitter	Solodised Solonetz	Sodosol	
		Karloo	**Solodised Solonetz**	**Sodosol**	**35**
	Duplex soils of relict plains	**Ilbilbie**	**Soloth**	**Sodosol**	**33**

The location of these soil mapping units in the Plane Creek district are shown in Figure 3.1.

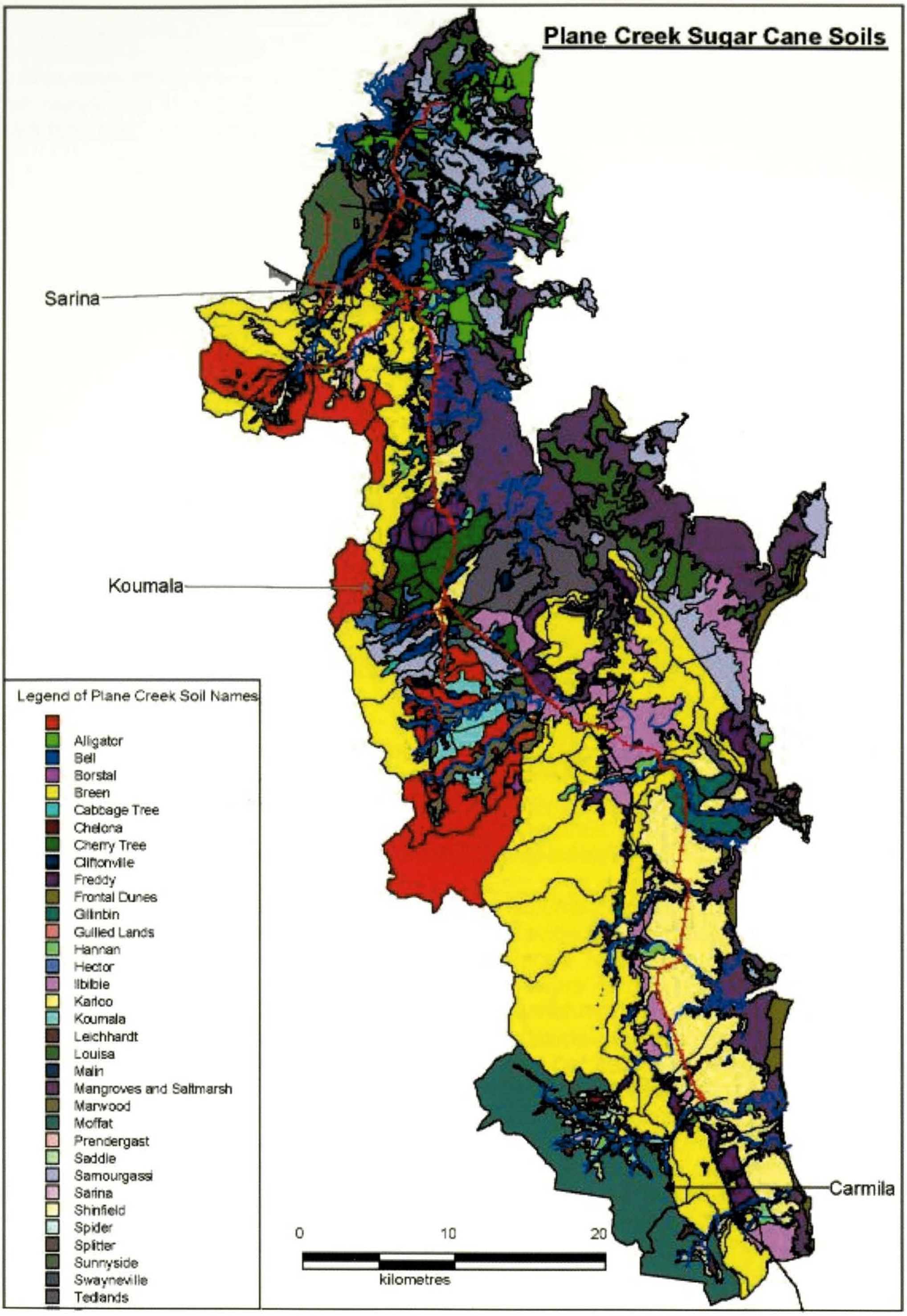


Figure 3.1 - Map of the Plane Creek district showing the major soil groups mapped at a scale of 1:250,000

Location of soils

Each soil type occurs in a particular part of the landscape often in association with other soils. Three landscape sections covering different parts of the Plane Creek district are shown in Figures 3.2, 3.3 and 3.4. They illustrate where each soil group occurs and their relationships with river systems and other topographic features.

Figure 3.2 - Typical landscape north of Sarina

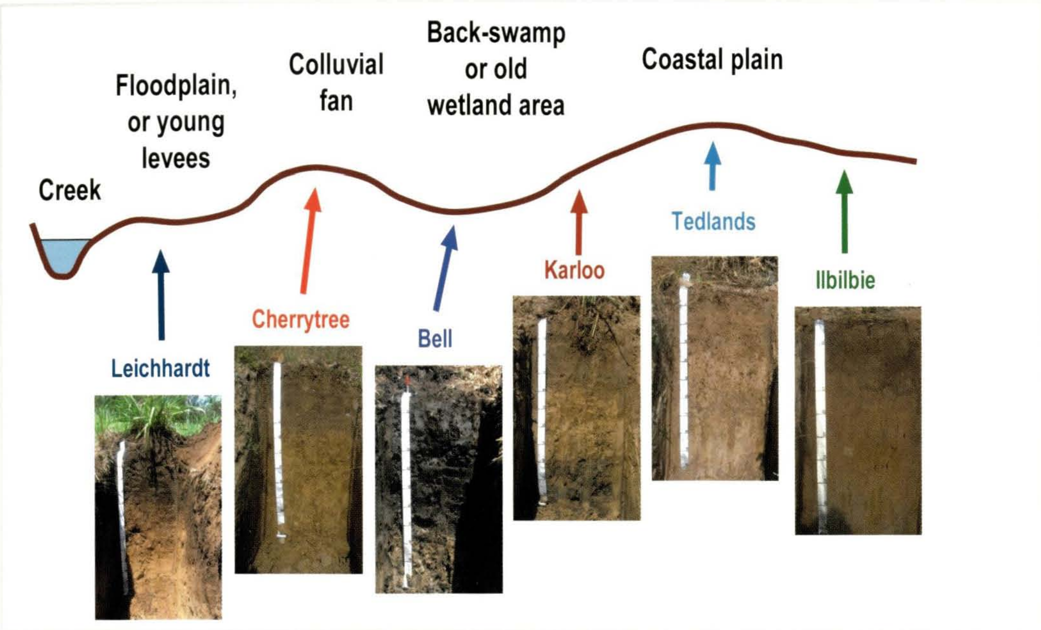


Figure 3.3 - Typical landscape north of Koumala

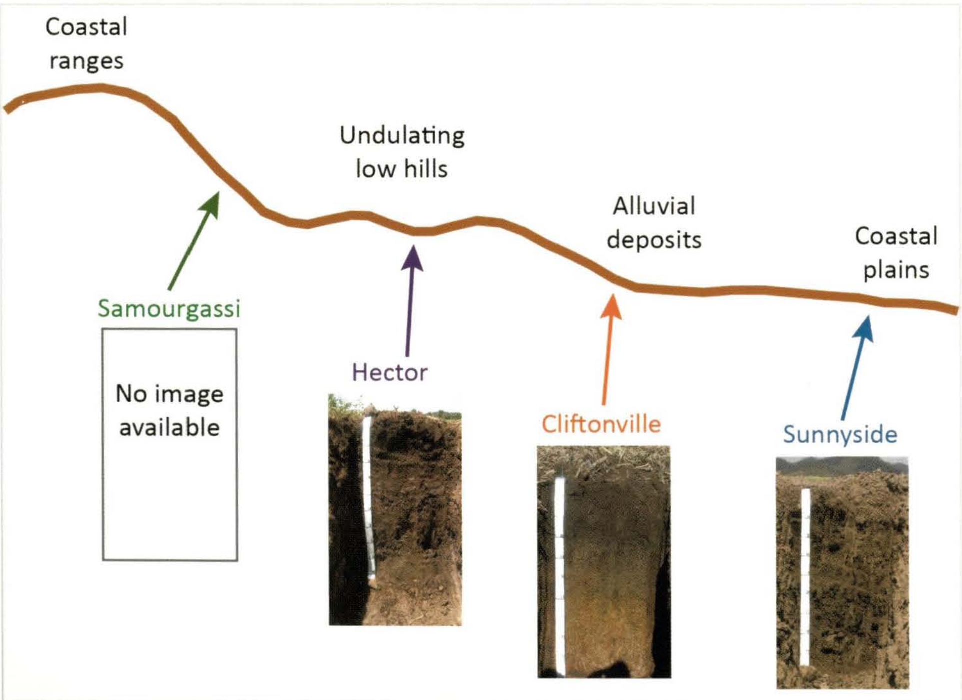
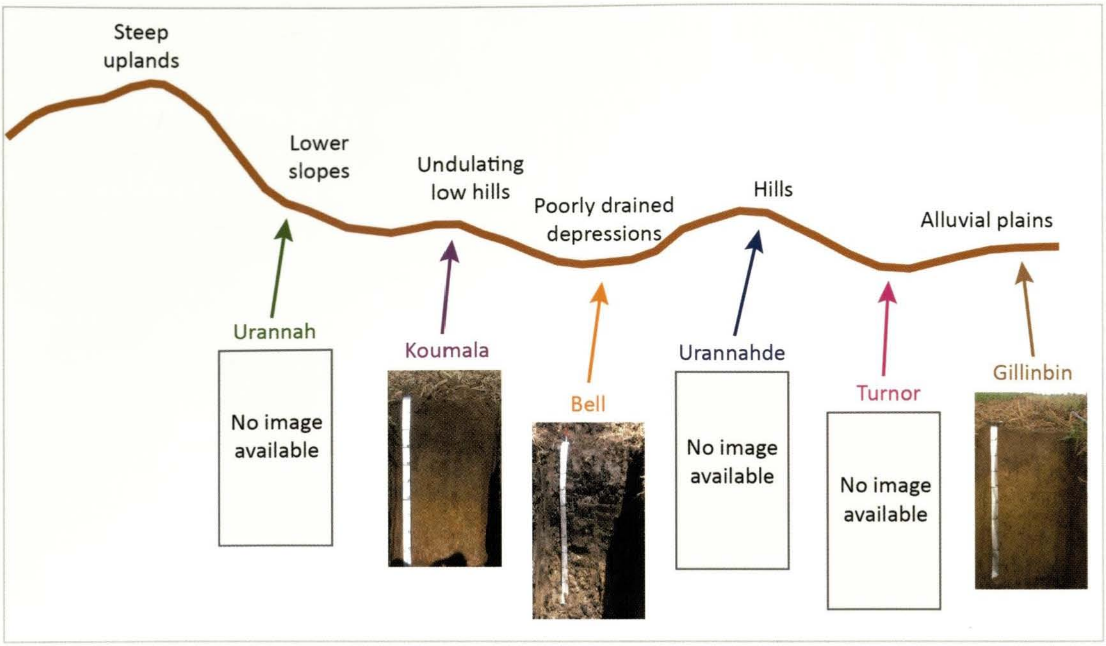


Figure 3.4 - Typical landscape south of Koumala



Soil reference sites

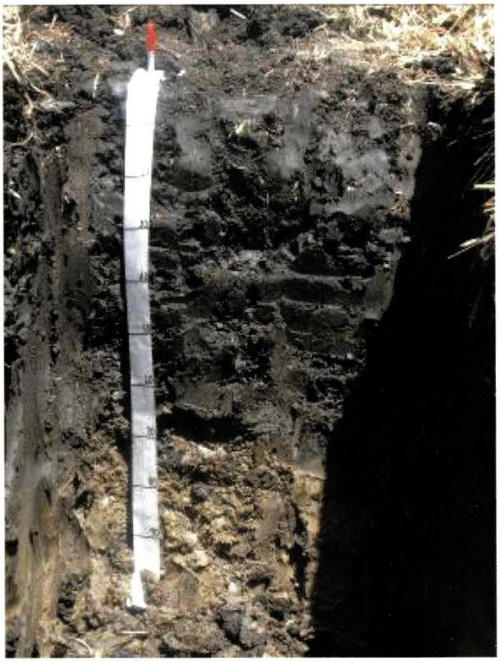
Twelve soil reference sites, representative of the major soil groups in the Plane Creek district, were established and are shown in bold in Table 3.1. Profiles were excavated for describing the field appearance of each soil type. Representative topsoil (0 - 20 cm) and subsoil (40 - 60 cm) samples were taken from the surrounding cane area. These samples were analysed in laboratories for a range of chemical and physical properties.

In the rest of this chapter, information on the occurrence, formation, field appearance and chemical and physical properties of these soils is provided in a two-page format. Bar graphs are used to represent the soil analytical data on a scale from very low to very high for each reference site and for similar soils sampled on growers' farms. Guidelines are given for the management of nutrient applications, tillage, water and environmental risks. Nutrient management guidelines are provided for different crop classes, such as fallow plant, replant and ratoons. However specific nutrient guidelines following the use of legume crops and mill by-products are not included and readers need to refer to the information in Chapter 2. The nutrient management guidelines for each soil type are based on soil conditions at the reference sites. They do not necessarily apply to a similar soil type occurring on your farm as you may have managed it differently. The guidelines are only intended to be used as a broad guide for nutrient inputs in situations where recent soil and / or leaf tests are not available for specific blocks. We recommend that you take soil and leaf tests for each block on your farm so that you can be sure what nutrients are required.

Bell (Bx) - Black cracking clay
Great soil group: Black earth
Australian soil classification: Vertosol

Occurrence: These soils occur around Bell's Creek north of Sarina and to the west of Koumala. They occupy about 3% of the sugarcane area in the Plane Creek district.

Formation:
They are formed in low-lying areas where water accumulates and floods deposit fine silts and clays. They have developed on fine outwash material derived from volcanic rocks.


Bell soil profile


Bell soil west of Koumala.

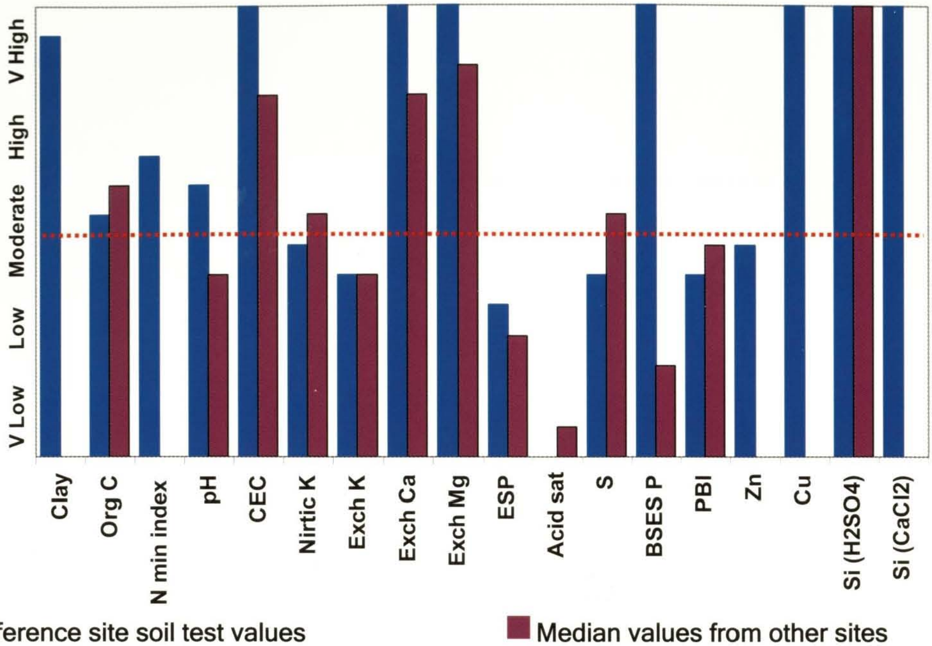
Field appearance:
Topsoils are black cracking clays. Surface cracks can be 3-5 cm wide during the dry season. Subsoils are grey to yellowish grey with distinct yellow mottles. They have a high content of clay. Lime nodules often occur at depth.

Similar soils:
Spider is a related soil in the Plane Creek district and Victoria Plains in the Mackay district.

Physical properties:
They have a very high clay content with shrink-swell characteristics and these soils are self-mulching. They have a high plant available water capacity (100-120 mm). They are poorly drained and susceptible to frequent waterlogging. They have an excellent surface structure and are not hard-setting. Rooting depth is restricted to less than 1 m due to the heavy clay texture of the subsoil and shallow water table.

Chemical properties:
These soils have a high fertility status. Topsoils are slightly acid to neutral and pH increases to alkaline at depth. Organic carbon and the N mineralisation index are moderately high. BSES P is variable according to the history of fertiliser use. Topsoils have a moderate P-sorbing capacity. CEC is extremely high and exchangeable cations such as Ca and Mg are at very high levels and increase with depth, consistent with an increase in clay content. Exchangeable and non-exchangeable K reserves are moderate. There is no evidence of micronutrient deficiencies. Silicon levels are very high.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N* kg/ha	P kg/ha	K Kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	100	0	50	5	0	0	0
Replant	0	120	0	100	5	0	0	0
Ratoon	0	120	0	100	5	0	0	0

* Based on the organic C content and N mineralisation index, this soil requires 100 and 120 kg N /ha for plant and ratoon cane respectively. However, due to the risk of N losses by denitrification caused by waterlogging, N fertiliser application rates may need to be increased.

Tillage and water management:

It is difficult to obtain a good tilth with these soils and there is a restricted moisture range for effective tillage. Cultivating these soils when too wet will cause smearing and when too dry will cause large clods. If compaction occurs, these soils have an ability to self-repair due to their shrink-swell properties, and excessive ripping is not required. The impact of high water tables can be alleviated by mound planting and controlled-traffic systems. Overhead irrigation is recommended for these soils because of their low permeability. Short irrigation duration times should be used to take advantage of rapid water entry when surface cracks are visible. Drains may be necessary to intercept water and improve on-site drainage.

Environmental risk management:

Denitrification is a risk due to frequent waterlogging. Strategies to reduce nitrogen losses include mound planting, placement of nitrogen fertiliser into the mound and split fertiliser applications. Split applications may be impractical as access is limited by soil wetness. Harvesting times need to be scheduled as early as possible so that ratoons are well advanced before the wet season and the impact of waterlogging on nitrogen losses and early growth is reduced.

Cherry Tree (Ch) - Grey brown duplex soil
Great soil group: Solodic / Solodized Solonetz
Australian soil classification: Sodosol

Occurrence: These soils are most extensive in the alluvial plains of the Koumala area and occur close to Cherry Tree and Duff creeks. They occupy about 5% of the sugarcane area in the Plane Creek district.

Formation:
These soils have formed on an old outwash area of coarse colluvial material following the courses of Cherry Tree and Duff creeks. Parent material is mixed due to inputs from three geological units.

Cherry Tree soil profile

Cherry Tree soil near Koumala

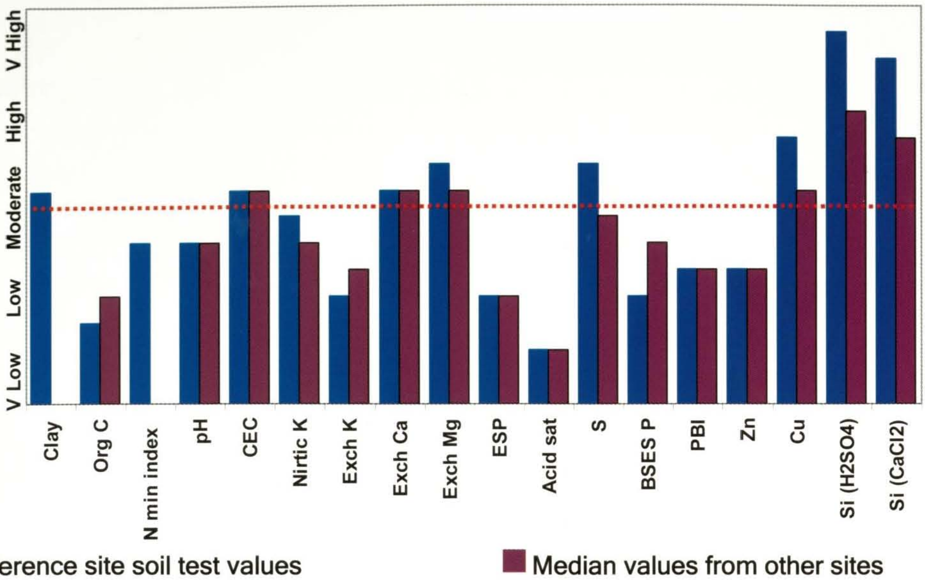
Field appearance:
The topsoil is greyish brown clay loam whilst the subsoil is grey to yellowish brown clay. Reddish brown mottles commonly occur in the subsoil and abundant large iron and manganese nodules occur at depth, making the soil gravelly.

Similar soils:
Sunnyside in the Plane Creek district and Calen in the Mackay district.

Physical properties:
These soils are imperfectly drained with intermittent waterlogging. They have a moderate plant available water capacity (70-80 mm). Topsoils are prone to hard-setting and compaction. Subsoils are occasionally sodic below 800 mm, resulting in restricted rooting depth and poor permeability.

Chemical properties:
These soils have a moderately low nutrient status. Topsoils are acidic with a moderate CEC and aluminium saturation of around 10%. The CEC and exchangeable cations increase gradually with depth, consistent with an increase in clay content. Organic carbon and N mineralisation index are moderately low. Potassium reserves and exchangeable K are moderate. Although the reference site has low BSES P, this value will vary according to past fertiliser history. Topsoils have low P-sorbing capacities. There is no evidence of micronutrient deficiencies. Silicon is adequately supplied. Both pH and exchangeable sodium percentage increase with depth and some profiles have sodic subsoils.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn Kg/ha
Fallow plant	4*	130	30	50	0	0	0	0
Replant	4*	150	30	100	0	0	0	0
Ratoon	0	150	15	100	0	0	0	0

* based on soil pH.
Gypsum may also be required where subsoils are strongly sodic.

Tillage and water management:
It is difficult to obtain a good tilth and there is a restricted moisture range for effective tillage. The relatively high silt content of the topsoil makes these soils prone to hard setting. The risk of compaction can be reduced by adopting controlled-traffic. Green cane trash blanketing has greatly improved soil structure, tilth and porosity. These soils are suitable for both furrow and overhead irrigation. Care needs to be exercised when blocks are laser levelled to avoid exposure of sodic subsoils.

Environmental risk management:
Denitrification is a risk due to intermittent waterlogging. Strategies to reduce N losses include mound planting, placement of nitrogen fertiliser into the mound and split fertiliser applications. Excessive water shedding may be an impediment to mound planting and split applications may be impractical due to limited access.

Cliftonville (Cv) - Yellow brown duplex soil
Great soil group: Yellow podzolic
Australian soil classification: Chromosol

Occurrence: These soils occur on lower slopes of undulating low hills between Sarina and Hay Point. They commonly occur in association with Hector soils and occur below Hector soils on colluvial deposits that have accumulated in foot slope positions. They occupy about 3% of the sugarcane area in the Plane Creek district.

Formation:
These soils have formed on colluvial material derived from basic to intermediate volcanic rocks. Profiles have been influenced by downslope water movement causing the development of abundant iron and manganese nodules.

Excavating a Cliftonville soil profile

Cliftonville soil profile

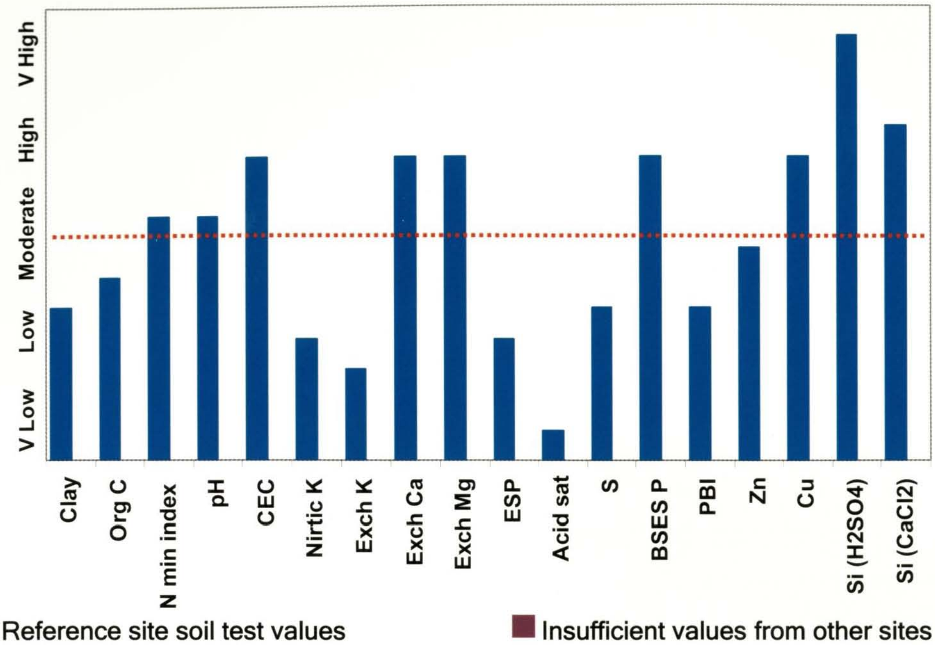
Field appearance:
They have dark brown sandy loam topsoils grading into grey brown sandy clay loam and yellowish brown to grey clay loam, with prominent and abundant reddish mottles. Iron and manganese concretions become more common in the lower part of the profile and can form a cemented hardpan. Some profiles can be stony or gravelly.

Similar soils:
Louisa, which is paler and more leached, occurs in the Plane Creek district and Mentmore in the Mackay district.

Physical properties:
Profiles are moderately well drained and reasonably permeable. They are affected by lateral water movement from higher up the slope. They have a moderately low plant available water capacity (65-75 mm). Rooting depths can be up to 1 m, depending on the depth of the cemented hardpan. They can be subject to erosion, depending on the slope.

Chemical properties:
These soils are weakly acidic with a moderate fertility. The CEC and levels of exchangeable cations are moderate in the topsoil although exchangeable K values and K reserves are low. The level of organic carbon and N mineralisation index are moderate. Phosphorus is adequately supplied in the topsoil at the reference site and the P-sorbing capacity is low. Sulphur values at the reference site are low. Copper, zinc and silicon all appear to be adequate.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	110	0	100	10	0	0	0
Replant	0	130	0	120	10	0	0	0
Ratoon	0	130	0	120	10	0	0	0

Tillage and water management:

These soils are prone to hardsetting and compaction which can be confined to inter-rows with controlled-traffic. Green cane trash blanketing and the application of organic amendments can improve soil structure and minimise surface crusting. If flood irrigated, U-shaped furrows are most suitable with medium flow rates, however overhead irrigation may help reduce losses to deep drainage. Plant available water capacity is moderate but is lower in the subsoil due to the presence of concretions and nodules.

Environmental risk management:

Loss of nitrogen by leaching or denitrification could occur with excessive rainfall or high irrigation rates soon after fertiliser application. Split fertiliser applications will reduce these risks. Cultivation of steeper slopes should be avoided. Grassed headlands and drains, green cane trash blanketing and minimum or zero tillage should be used to minimise the risk of erosion.

Gillinbin (Gb) - Red brown duplex soil
Great soil group: Soloth
Australian soil classification: Sodosol

Occurrence: These soils occur on gently sloping, older river terraces south of Koumala and predominantly along Marion and Gillinbin creeks. They occupy about 3% of the sugarcane area in the Plane Creek district.

Formation:
These soils have formed on alluvium occurring on older river terraces.

Gillinbin soil profile

Gillinbin soils near Ilbilbie

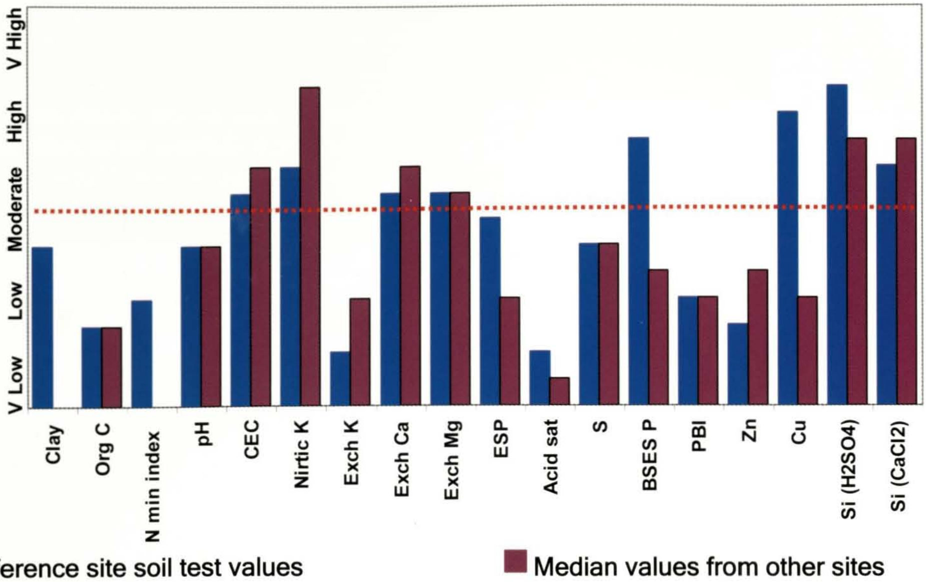
Field appearance:
They have deep, dark grey brown sandy clay loam topsoils with a weak structure grading into grey brown to yellow brown loam to clay loam. Subsoils are grey to brown clay with prominent yellow to red mottles and occasional iron and manganese concretions. The structure of the subsoil is moderate blocky.

Similar soils:
Prendergast is an alkaline equivalent in Plane Creek and Marian is similar around Mackay.

Physical properties:
These soils are moderately well drained with intermittent waterlogging. They have a moderately low plant available water capacity (65-75 mm). Rooting depth can be up to 1 metre. Topsoils are prone to hardsetting and compaction.

Chemical properties:
These soils are acidic with a moderate fertility. The CEC and levels of exchangeable cations are moderate in the topsoil although exchangeable K values are low. Reserves of K on the other hand are moderate. Organic carbon and N mineralisation index are low. Phosphorus is adequately supplied at the reference site and the P-sorbing capacity is low. Sulphur at the reference site is low. Copper is marginal in some grower samples whilst zinc is marginal at the reference site. ESP increases from 5% in the topsoil to over 13% in the 40-60 cm layer, and further increases in sodicity will impact on rooting depth.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	4*	140	20	50	0	0	10	0
Replant	4*	160	20	100	0	0	10	0
Ratoon	0	160	10	100	0	0	10	0

* based on soil pH.
Gypsum may also be required where subsoils are strongly sodic.

Tillage and water management:

These soils are generally easy to cultivate but can be prone to hardsetting and compaction. This can be confined to inter-rows with controlled-traffic. Green cane trash blanketing and the application of organic amendments can improve soil structure and tilth, and minimise surface crusting. If flood irrigated, U-shaped furrows are most suitable with medium flow rates, however overhead irrigation may help reduce losses to deep drainage. These soils are moderately well drained but laser levelling may be useful for improving surface drainage in some situations where the topography is very flat.

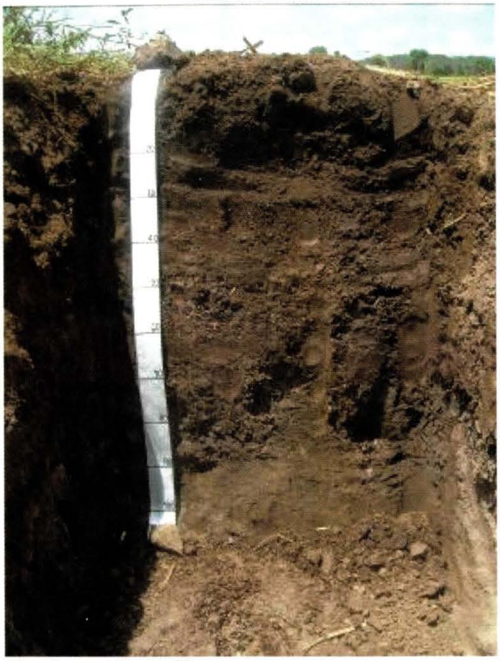
Environmental risk management:

Loss of nitrogen by leaching or denitrification could occur with excessive rainfall or high irrigation rates soon after fertiliser application. Split fertiliser applications will reduce these risks.

Hector (Ht) - Gravelly brown duplex soil
Great soil group: Prairie soil
Australian soil classification: Dermosol

Occurrence:
Hector soils occur on the undulating low hills north of Sarina and to the south-west of Koumala. Slopes range from 3-12%. They commonly occur below Samourgassi soils and above Cliftonville soils and occupy about 3% of the sugarcane area in the Plane Creek district.

Formation:
They have developed on basic to intermediate volcanic rocks and contain stones and gravels through the profile.


Hector soil profile


Excavating a Hector soil profile

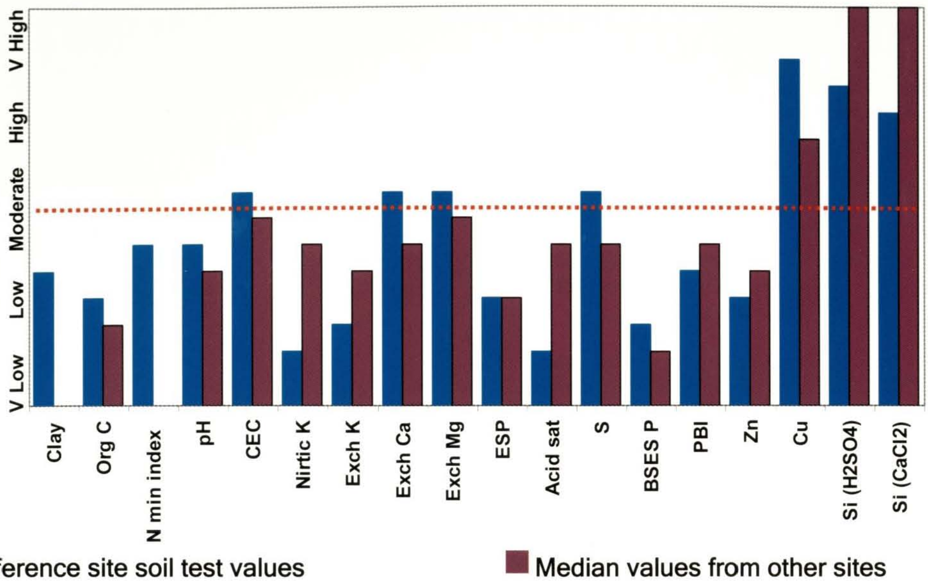
Field appearance:
Topsoils are well structured dark brown loams overlying dark reddish brown stony clay loam. Subsoils are brown to yellowish brown with distinct red mottles and a moderate blocky structure. There is an increasing amount of stones and rock down the profile.

Similar soils:
Swayneville in the Plane Creek district and Farleigh in the Mackay district.

Physical properties:
Profiles are well structured with a reasonable permeability and good internal drainage. They have a moderately low plant available water capacity (60-80 mm). Rooting depth can be up to 1 m depending on the amount of stones and rock in the profile. They can be subject to erosion, depending on slope. Overhead irrigation is recommended to avoid water losses by deep drainage.

Chemical properties:
These soils are moderately acidic and have a high fertility. The CEC and levels of exchangeable cations are moderate in the topsoil although exchangeable K and reserves of K are low at the reference site. Organic carbon and N mineralisation index are moderately low. Phosphorus is low at the reference site and also in some of the growers' soil analyses. The P-sorbing capacity is low. Sulphur values at the reference site are moderately high and micronutrients appear to be at adequate levels.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	4*	120	30	120	0	0	0	0
Replant	4*	140	30	120	0	0	0	0
Ratoon	0	140	15	120	0	0	0	0

* based on soil acidity

Tillage and water management:
These soils are prone to hardsetting and compaction, which can be confined to inter-rows with controlled-traffic. Green cane trash blanketing and the application of organic amendments will improve soil structure and minimise surface crusting. Overhead irrigation will help reduce water losses to deep drainage. Plant available water capacity is restricted by the presence of stones and concretions.

Environmental risk management:
Cultivation of steeper slopes should be avoided. Grassed headlands and drains, green cane trash blanketing and minimum or zero tillage should be used to minimise the risk of erosion. Nutrient losses by leaching and lateral water movement can occur. Split application of fertilisers is recommended to reduce these losses.

Ilbilbie (Ib) - Grey duplex soil
Great soil group: Soloth
Australian soil classification: Sodosol

Occurrence: Ilbilbie soils occur on the alluvial plains north of Ilbilbie with scattered occurrences along the main highway from Ilbilbie to Flaggy Rock. They occupy about 5% of the sugarcane area in the Plane Creek district.

Formation:
These soils have developed on alluvium on the coastal plains. They are usually associated with a discontinuous cemented hardpan formed from the underlying rocks.

Ilbilbie soil profile

North of Ilbilbie

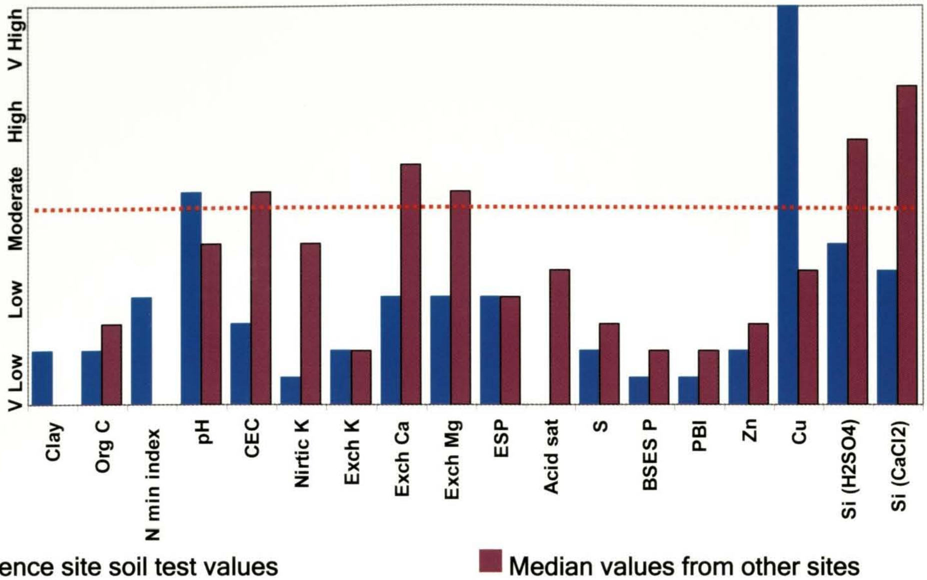
Field appearance:
These soils have a dark grey brown sandy loam topsoil with a massive structure. Subsoils are grey to light grey with a sandy clay loam to clay loam texture and moderate angular blocky structure. Distinct yellow mottles and iron and manganese concretions are common. A cemented hardpan commonly occurs at about 1 m.

Similar soils:
They are similar to Kinchant and Slater soils in the Mackay district.

Physical properties:
Topsoils are massive and sandy with a high permeability. They have a low plant available water capacity (50-60 mm). Profiles are imperfectly drained and intermittently waterlogged due to the cemented hardpan. Root development is restricted by the depth of the hardpan.

Chemical properties:
The reference site topsoil is slightly acidic but growers' samples have a lower pH. The reference soil has a low fertility status with low organic carbon and N mineralisation index, low ECEC and low levels of BSES P, sulphur and exchangeable potassium, calcium and magnesium. Potassium reserves are moderate. The reference soil is low in zinc and silicon and some of the growers' samples are low in zinc. It is suggested that micronutrient and silicon levels be monitored on these soils by means of leaf analysis. They have a very low P-sorbing capacity which makes it difficult for these soils to retain P fertiliser. Extremely low calcium levels are found in the sub-soil. ESP increases from 2% in the topsoil to almost 30% in the 40-60 cm layer, making this a strongly sodic soil and this will influence rooting depth.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha	Si** kg/ha
Fallow plant	1*	130	30	100	25	0	0	10	yes
Replant	1*	150	30	100	25	0	0	10	yes
Ratoon	0	150	20	100	25	0	0	0	0

* Based on exchangeable Ca. Gypsum may be more appropriate where subsoils are strongly sodic.

**As the Si values for the reference site are both below the critical values, the application of a silicon amendment should be considered on these soils.

Tillage and water management:

Frequent light overhead irrigations should be used due to the sandy nature of these soils and their low plant available water capacity. Green cane trash blanketing and the application of organic amendments will improve soil structure, tilth and plant available water capacity. Minimum or zero tillage in association with controlled-traffic is recommended for these soils.

Environmental risk management:

Loss of nitrate by leaching and lateral movement can occur during periods of excessive rainfall or after irrigation. To reduce this risk it is recommended that fertiliser applications be split. There is a risk of off-site movement of P due to their low P-sorbing capacity so care needs to be taken not to apply too much P fertiliser in a single application.

Karloo (Kl) - Grey brown duplex soil
Great soil group: Solodic / Solodized Solonetz
Australian soil classification: Sodosol

Occurrence: They are a major sugarcane producing soil of the coastal lowlands and occur mainly south of Ilbilbie and to the east of the Bruce Highway. They are closely associated with isolated areas of Ilbilbie soils. They occupy about 15% of the sugarcane area in the Plane Creek district.

Formation:
These soils are formed on a combination of marine sediments and river alluvium.


Karloo soil profile


Karloo soil landscape

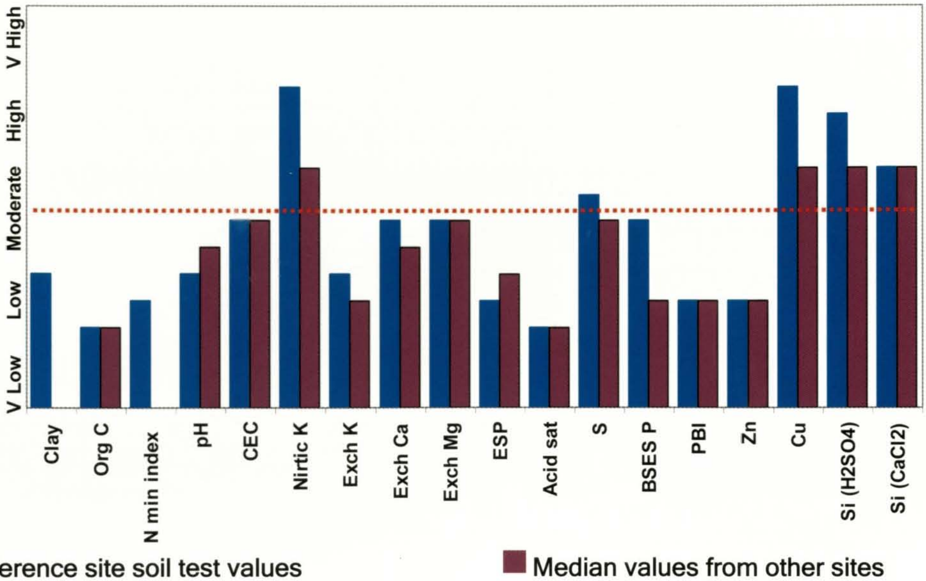
Field appearance:
They have brown to grey brown sandy loam topsoil with a massive structure. This overlies yellowish brown clay loam to clay with distinct yellow mottles. The lower part of the profile has dark grey brown clay with a moderate angular blocky structure and yellow mottles with iron and manganese concretions.

Similar soils:
They are similar to Narpi soils in the Mackay district.

Physical properties:
While the topsoils are permeable, imperfectly drained subsoils result in seasonal waterlogging. They have a moderately low plant available water capacity (75-85 mm). Subsoils can be sodic and this will affect rooting depth. Topsoils are susceptible to surface crusting.

Chemical properties:
Topsoils are acidic and have a moderately low fertility status. Organic carbon and N mineralisation index are low, BSES P, exchangeable K and sulphur are at moderate levels whilst potassium reserves are high. Topsoil CEC and levels of calcium and magnesium are moderate and increase markedly with depth. Topsoil ESP is low but increases to around 8% in the 40-60 cm layer. Micronutrients need to be monitored as deficiencies have been detected at some sites.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K Kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	4*	130	20	80	10	0	0	0
Replant	4*	150	20	100	10	0	0	0
Ratoon	0	150	10	100	10	0	0	0

* Based on soil pH.

Gypsum may also be required where subsoils are strongly sodic.

Tillage and water management:

Topsoils are prone to hardsetting and compaction. This can be reduced by adopting controlled-traffic. Green cane trash blanketing and the application of organic amendments will improve soil structure, tilth and plant available water capacity. Minimum or zero tillage in association with controlled-traffic is recommended for these soils. Frequent light irrigations should be used due to the sandy nature of the topsoil and the low plant available water capacity.

Environmental risk management:

Loss of nitrate by leaching and lateral water movement can occur during periods of excessive rainfall or after irrigation. To reduce this risk it is recommended that fertiliser applications be split. Loss of nitrogen by denitrification is also a risk due to seasonal waterlogging and restricted subsoil drainage. Split fertiliser applications are again recommended to reduce these potential losses.

Koumala (Km) - Yellow duplex soil
Great soil group: Yellow podzolic
Australian soil classification: Chromosol

Occurrence: Koumala soils occur mainly in the area to the south of Koumala and are associated with Urannah soils. Urannah soils occur on steeply sloping upland areas whilst the Koumala soil occurs on the lower slopes of undulating hills on granite. They occupy about 5% of the sugarcane area in the Plane Creek district.

Formation:
They have formed on slopes of 3-12% and have developed in weathered material derived from granite rocks. Most of the material has developed on-site but some downslope movement of soil material has probably also occurred.

Landscape with Koumala soils

Koumala soil profile

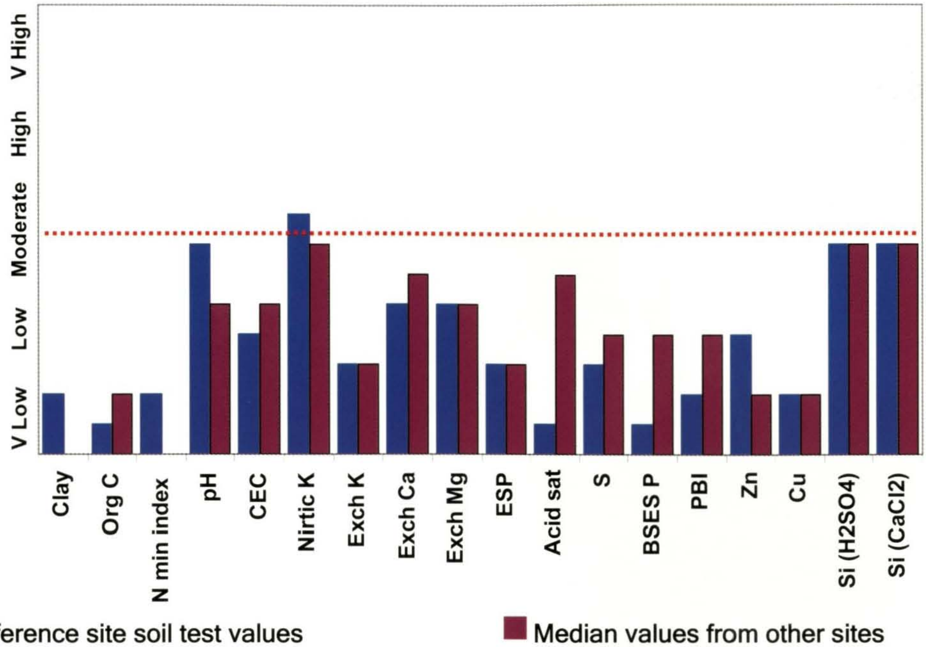
Field appearance:
The topsoil of this duplex soil is brown loamy sand to sandy loam with a massive structure. This overlies strong brown sandy clay loam which is again massive. Below this is yellowish brown sandy clay loam to clay loam with a weak to moderate blocky structure.

Similar soils:
The Koumala soil most closely resembles the Dunwold soil of the Mackay district.

Physical properties:
Topsoils are massive and sandy with a high permeability. They have a low plant available water capacity (50-70 mm). Rooting depth can be up to 1m depending on the amount of stones in the profile. These soils are subject to erosion, given that they occur on slopes of up to 12%. Overhead irrigation is recommended to avoid water losses by deep drainage.

Chemical properties
Topsoils are slightly acidic with a low fertility status. Organic carbon, N mineralisation index and ECEC are very low and there are low levels of BSES P, sulphur and exchangeable potassium, calcium and magnesium. Potassium reserves are moderate. Both the reference soil and growers' samples are low in copper, and zinc is low in some grower samples. Silicon levels are marginal. It is suggested that micronutrient and silicon levels be monitored on these soils using leaf analysis. They have a very low P-sorbing capacity which makes it difficult for these soils to retain P fertiliser.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0	140	30	80	25	0	10	0
Replant	0	160	30	100	25	0	10	0
Ratoon	0	160	20	100	25	0	0	0

Tillage and water management:

Frequent light overhead irrigations should be used due to the sandy nature of these soils and their low plant available water capacity. Green cane trash blanketing and the application of organic amendments will improve soil structure, tilth and plant available water capacity. Minimum or zero tillage in association with controlled-traffic is recommended for these soils to reduce the risk of erosion.

Environmental risk management:

Loss of nitrate by leaching can occur during periods of excessive rainfall or after irrigation. To reduce this risk it is recommended that fertiliser applications be split. There is also a risk of off-site movement of P due to their low P-sorbing capacity so care needs to be taken not to apply too much P fertiliser in a single application. Where these soils occur on slopes, they are prone to erosion. This can be minimised with grassed headlands and waterways, minimum or zero tillage and green cane trash blanketing.

Leichhardt (Lh) - Brown alluvial loam
Great soil group: Alluvial soil
Australian soil classification: Rudosol

Occurrence: These soils occur sporadically throughout the area on river floodplains associated with major creeks. Floodplains in the Plane Creek district occur mainly in the upper part of the catchments of rivers flowing to the coast. Lower down the rivers have cut into the alluvial deposits of the coastal plain, and river floodplains and terraces have not developed. Leichardt soils occupy 3 - 5% of the sugarcane area in the Plane Creek district.

Formation:
These loamy soils are formed from river alluvium of mixed parent material deposited during flood events.

Leichhardt soil profile

Leichhardt soil adjacent to Station Creek west of Koumala

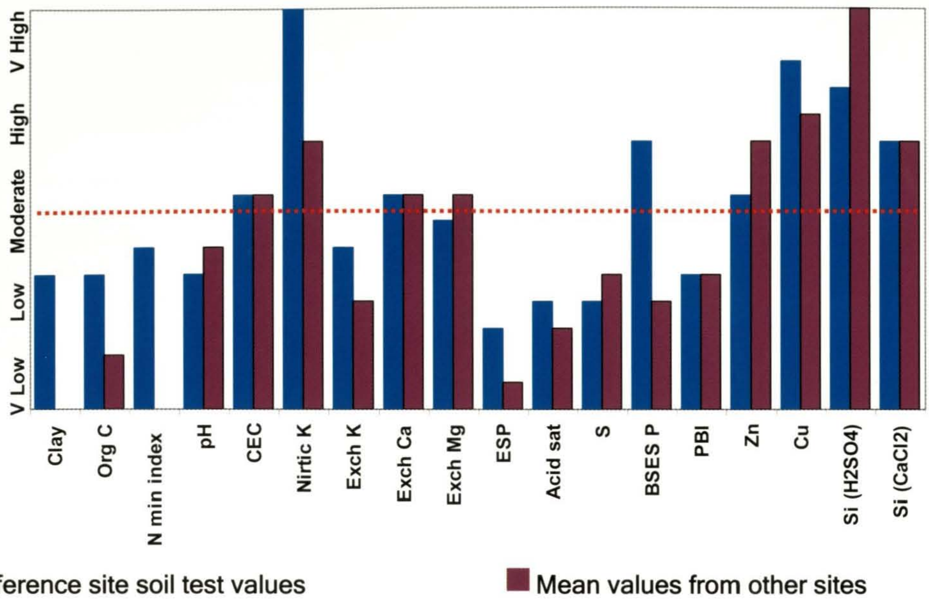
Field appearance:
These dark brown gradational soils generally contain cobble stones. Texture changes from sandy loam at the surface to sandy clay loam at depth. The colour of the subsoil varies from yellow brown to red brown.

Similar soils:
Hannan soils, which occur on terraces and river levees, are similar although they do not have river cobbles.

Physical properties:
Leichhardt soils are freely draining and have a low plant available water capacity (50-60 mm). Effective rooting depth is at least 1 m. These soils are not prone to hardsetting nor compaction and therefore have few physical constraints to crop growth. Overhead irrigation is recommended to avoid water losses by deep drainage.

Chemical properties:
These soils are acidic and have a moderate fertility. Organic carbon and N mineralisation index are moderately low. Their moderate CEC increases with depth which is consistent with increased clay content. Exchangeable K is moderate and reserve potassium is high. Topsoils have low P-sorbing capacities. The BSES P is high in the reference site, but is generally lower in growers' samples, reflecting their P fertiliser history. Sulphur is low in both the reference site and in growers' samples. Micronutrients and silicon are well supplied.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P Kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	4*	120	0	0	15	0	0	0
Replant	4*	140	0	80	15	0	0	0
Ratoon	0	140	0	80	15	0	0	0

* Based on soil pH

Tillage and water management:

These soils are easily cultivated and a good tilth can be easily achieved. Supplementary irrigation is needed to reach yield potential and overhead application is recommended due to high infiltration rates. These soils are also suited to controlled-traffic and permanent bed systems.

Environmental risk management:

These soils are prone to erosion due to flooding. Soil cover should be maintained if possible and tillage avoided during the flood risk periods. Nitrate loss by leaching is a risk and split applications of N fertiliser are recommended. Loss of P by leaching is only a slight risk as PBI levels are reasonable in most profiles.

Marwood (Mw) - Gleyed duplex soil
Great soil group: Gleyed podzolic
Australian soil classification: Chromosol

Occurrence: Marwood soils occur on the lower slopes of a small area of hills north of Sarina. They occupy around 3% of the sugarcane area in the Plane Creek district.

Formation:
These soils have formed in weathered material derived from granite that contains large quantities of coarse gritty sand.


Marwood soil profile


Malin and Marwood soils north of Sarina

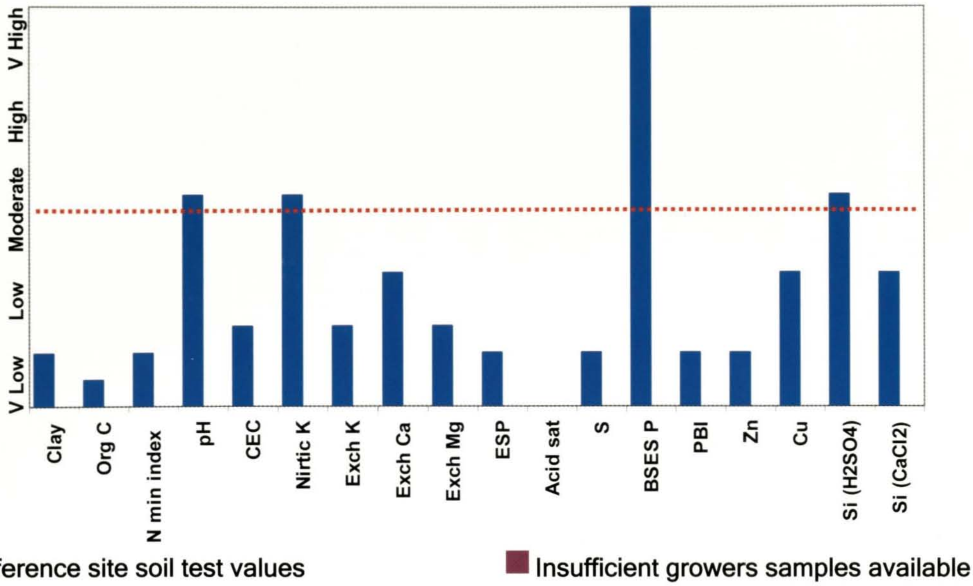
Field appearance:
Topsoils are massive dark grey brown loamy coarse sand. Subsoils are massive yellowish brown coarse sandy loams, grading into light grey coarse sandy clay loams with distinct yellow mottles.

Similar soils:
Malin and Marwood soils occur together: Malin on undulating upper slopes and Marwood on lower slopes.

Physical properties:
These coarse sandy soils are susceptible to drought as they have a low plant available water capacity (50-70 mm). Topsoils are massive and sandy with a high permeability. Rooting depth can be up to 1 m depending on the amount of stones and rock in the profile. Soils on steeper slopes are subject to erosion. Overhead irrigation is recommended to restrict water losses by deep drainage.

Chemical properties:
Marwood soils have a low fertility due to their very low organic carbon, low CEC and losses of nutrients through leaching. ECEC is very low and all exchangeable nutrients occur at low levels. Whilst topsoil pH is above 6, mag-lime is recommended to supplement low exchangeable calcium and magnesium levels. Exchangeable potassium is extremely low but K reserves are moderate. BSES P is high in the reference soil but P-sorbing capacity is very low making it difficult for these soils to retain P fertiliser. The reference soil has very low levels of sulphur and zinc. It is suggested that micronutrient and silicon levels be monitored on these soils using leaf analysis.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N Kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	0.5*	140	0	80	25	75	0	10
Replant	0.5*	160	0	100	25	75	0	10
Ratoon	0	160	0	100	25	0	0	0

*Based on exchangeable calcium level. Higher rates of mag-lime are suggested to supply both calcium and magnesium requirements.

Tillage and water management:

Frequent light overhead irrigations should be used due to the sandy nature of these soils and their low plant available water capacity. Green cane trash blanketing and the application of organic amendments will improve soil structure, tilth and plant available water capacity. Tillage should be kept to a minimum to conserve moisture and organic matter. Minimum or zonal tillage in association with controlled-traffic is recommended for these soils.

Environmental risk management:

Loss of nitrate by leaching can occur during periods of excessive rainfall or after irrigation. To reduce this risk it is recommended that fertiliser applications be split. There is also a risk of off-site movement of P due to their low P-sorbing capacity so care needs to be taken not to apply too much P fertiliser in a single application. Where these soils occur on slopes, they are prone to erosion. This can be minimised with grassed headlands and waterways, minimum or zero tillage and green cane trash blanketing. Without erosion control measures there is a risk of off-site movement of sediment and attached nutrients. Sub-surface application of nutrients is recommended.

Sunnyside (Su) - Grey duplex soil
Great soil group: Solodic / Solodized Solonetz
Australian soil classification: Sodosol

Occurrence: Sunnyside soils occupy the coastal floodplains on the eastern side of Alligator Creek, and are an extension of a much larger area of similar soils on the western side, in the Mackay district. They occupy about 10% of the sugarcane area in the Plane Creek district.

Formation:
These soils have developed on alluvium on the coastal plains adjacent to Alligator Creek.

Sunnyside soil profile

Sunnyside soil landscape

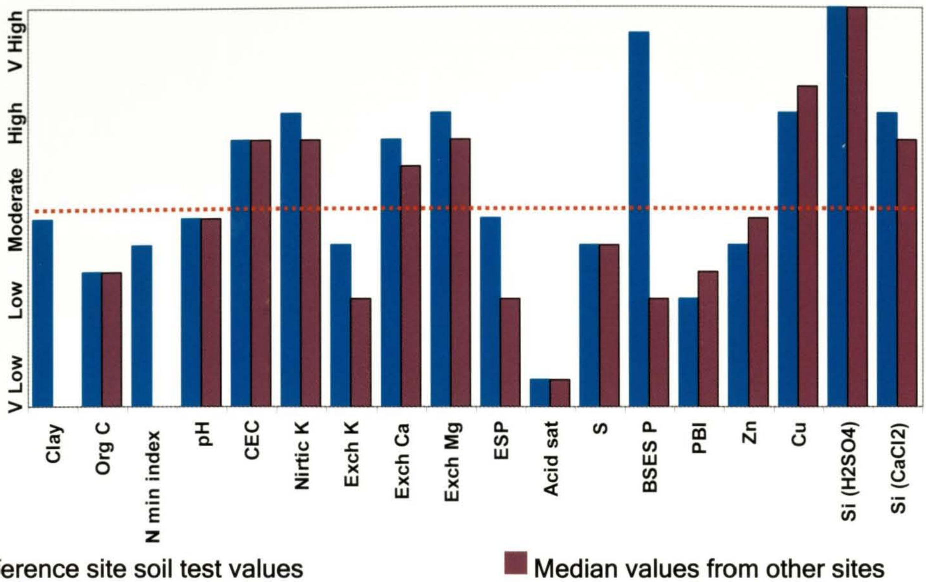
Field appearance:
This duplex soil has a dark brown loamy topsoil with a weak granular structure. Subsoils are grey clay with conspicuous yellow mottles and a moderate angular blocky structure.

Similar soils:
Alligator soils in the Plane Creek area and Calen and Sandiford soils in the Mackay district.

Physical properties:
These soils have moderate plant available water capacity (70-80 mm). However the shallow surface soil overlying relatively impermeable, often sodic clay, limits rooting depth. Topsoils are prone to hardsetting and compaction due to their high content of fine sand and silt. Drainage is imperfect to poor. Some areas may be susceptible to salinisation due to seepage of saline water from surrounding upland areas.

Chemical properties:
These soils are moderately fertile. Topsoils are slightly acidic with a high CEC which increases with depth, consistent with clay content. Organic carbon and N mineralisation index are moderately low. Exchangeable K is low whilst K reserves are moderate. Although the reference site has moderate BSES P, the growers' samples are much lower, and this value will vary according to past fertiliser history. There is no evidence of micronutrient deficiencies and silicon is adequately supplied. Sub-soils are neutral to alkaline and are often sodic.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn Kg/ha
Fallow plant	0	120	0	50	10	0	0	0
Replant	0	140	0	100	10	0	0	0
Ratoon	0	140	0	100	10	0	0	0

Gypsum may also be required in situations where subsoils are strongly sodic.

Tillage and water management:

These soils are generally easy to cultivate but the high content of fine sand or silt makes the surface soil prone to hardsetting and can make tillage difficult if the soil is too wet or too dry. The risk of compaction can be reduced with controlled-traffic and minimum tillage. Green cane trash blanketing and the application of organic amendments can improve soil structure and tilth and minimise surface crusting. Furrow irrigation is widely used on these soils, but infiltration may be restricted because of the silty nature of the topsoil. Greater frequency of irrigation events is required. Tail-water recycle pits are recommended to maximise irrigation efficiency and minimise water run-off and associated nutrient losses. Care needs to be exercised when blocks are laser levelled to avoid exposure of sodic sub-soils.

Environmental risk management:

Loss of nitrogen by denitrification is a risk due to intermittent waterlogging. Strategies to reduce losses include mound planting, placement of nitrogen fertiliser into the mound and split fertiliser applications. Split applications may be impractical due to limited access during wet periods.

Tedlands (Tl) - Grey yellow duplex soil
Great soil group: Soloth to Solodic / Solodized Solonetz
Australian soil classification: Sodosol

Occurrence: Tedlands soils are a major sugarcane producing soil of the coastal lowlands and occur mainly to the north and east of Koumala. They occupy about 5-10% of the sugarcane area in the Plane Creek district.

Formation:
These soils are formed on a combination of marine sediments and river alluvium.


Tedlands soil profile


Tedlands soil landscape

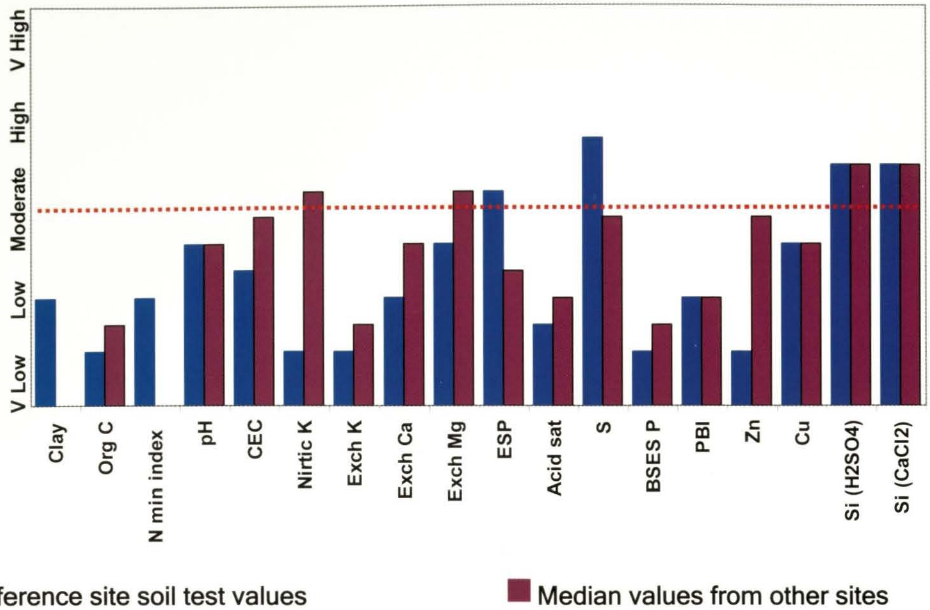
Field appearance:
Topsoils are massive brown sandy loams. Subsoils are weakly structured yellowish brown clay loam to clay with distinct yellow mottles and iron and manganese concretions are common. More uniform grey clay with fewer mottles occurs below this layer.

Similar soils:
It is similar to Cherry Tree soil but lacks the coarse gravel. It is similar to Eton soil in the Mackay district.

Physical properties:
They are reasonably permeable soils with an imperfect drainage due to a seasonally high watertable. They have a low plant available water capacity (50-70 mm). Subsoils can be sodic and this will affect rooting depth. Topsoils are susceptible to hard setting.

Chemical properties:
These soils have a low fertility with acidic topsoils and sodic subsoils. Organic carbon, N mineralisation index, BSES P, ECEC, exchangeable K and Ca are all low. Potassium reserves and zinc levels are also low. Topsoil ESP is around 10% increasing to 15% in the 40-60 cm layer, and further increases will impact on rooting depth.

Reference site and grower soil sample median analysis data



Nutrient management guidelines based on the reference site data:

Crop situation	Lime t/ha	N Kg/ha	P kg/ha	K kg/ha	S kg/ha	Mg kg/ha	Cu kg/ha	Zn kg/ha
Fallow plant	2.5*	130	30	100	0	0	0	10
Replant	2.5*	150	30	120	0	0	0	10
Ratoon	0	150	15	120	0	0	0	0

* Based on soil pH.
Gypsum may also be required where subsoils are strongly sodic.

Tillage and water management:

Topsoils are prone to hardsetting and compaction. This can be reduced by adopting controlled-traffic. Green cane trash blanketing and the application of organic amendments will improve soil structure, tilth and plant available water capacity. Minimum or zero tillage in association with controlled-traffic is recommended for these soils. Frequent light irrigations should be used due to the sandy nature of the topsoils and their low plant available water capacity.

Environmental risk management:

Loss of nitrate by leaching can occur during periods of excessive rainfall or after irrigation. To reduce this risk it is recommended that fertiliser applications be split. Loss of nitrogen by denitrification is also a risk due to seasonal waterlogging and restricted subsoil drainage. Split fertiliser applications are again recommended to reduce these potential losses.

CHAPTER 4

Nutrient requirements for specific blocks of sugarcane

The guidelines for managing nutrient inputs according to soil type (Chapter 3) should be refined for specific blocks of cane by making use of some important tools such as soil testing, leaf analysis, juice analysis and an integrated nutrient management package.

Soil testing

Soil testing provides useful information about the chemical (and some physical) properties of a soil and serves as a basis for determining specific nutrient inputs for a particular block of sugarcane. There are four important steps involved in this process. Each of these needs to be carried out with care to ensure meaningful results.

Step 1. Sample collection

Collect soil samples according to the guidelines provided in Appendix 2.

Step 2. Sample analysis

Submit samples to a reputable laboratory for analysis.

Step 3. Interpretation of results and calculating nutrient inputs

Ensure sound interpretation of the results and appropriate fertiliser recommendations by having an understanding of the basic process and getting advice from capable advisers such as extension officers.

Step 4. Fertiliser applications

Apply fertilisers at the appropriate rates and keep records of nutrient inputs.

Interpretation of soil test values

With the exception of N, soil tests are interpreted by comparing the actual soil analysis data with established critical values. As shown in Figure 4.1, a critical value for a particular nutrient is that soil test value above which any further yield response to the applied nutrient is unlikely.

Soil test results therefore indicate those nutrients which are present in adequate quantities (and are readily available to the crop), and those nutrients which are lacking (and need to be applied). As indicated in Chapter 2, nitrogen requirement is based on the yield potential for the district and the N mineralisation index, which depends on the organic carbon content (%) of the soil. Actual soil test values are interpreted by using the information provided in Chapter 2.

An example of a soil test report (Figure 4.2) shows the numerical soil test values from a commercial laboratory (column 2) and a representation of these values within the range from low (deficient) to excess/toxic. These values are used to assess the amount of each nutrient required by the crop for optimum production.

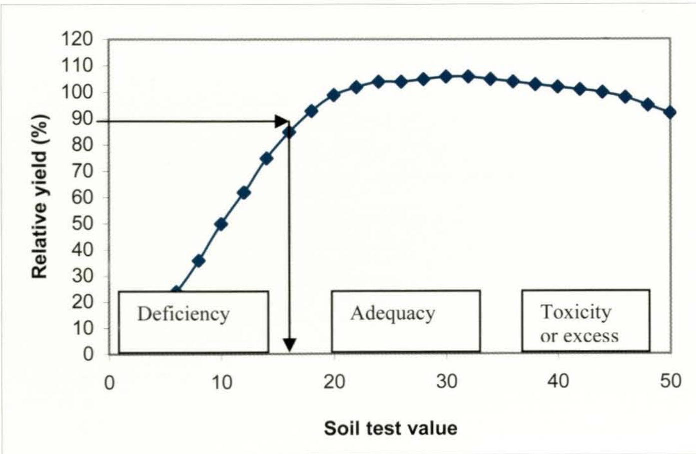


Figure 4.1 An example of a nutrient response curve for sugarcane.

Soil test report							
Trading Name: Bloggs & Bloggs		**Field Name:** Block 1					
Location: Plane Creek District		**Section of Field:** A					
Contact Name: Joe Bloggs		**GPS Latitude:**		**GPS Longitude:**			
Work Phone:		**Sample type:**		**Depth:** 0-20 cm			
Adviser:		**Lab Report Number:**		**Sampling Date:**			
Phone:		**Crop:** Sugarcane					
		Stage: Plough-out/Replant		**Target Yield:** 120 tonnes/ha			
		Low	<Optimum	Satisfactory	>Opt/ Norm	High	Excess/ Toxic
pH (1:5 water)	5.8						
Electr. Conduct dS/m	0.04						
Organic C (%)	1.3						
Sulphate S (MCP) mg/kg	5						
P (BSES) mg/kg	80						
K (Nitric) me%	0.9						
K (Amm. Acetate) me%	0.16						
Ca (Amm. Acetate) me%	2.2						
Mg(Amm.Acetate) me%	1.0						
Aluminium (KCl) me%	0.04						
Na (Amm. Acetate) me%	0.07						
Copper (DTPA) mg/kg	0.45						
Zinc (DTPA) mg/kg	0.8						
Zinc (HCl) mg/kg	1.4						
Mn (DTPA) mg/kg	11						
Silicon ($CaCl_2$) mg/kg	28						
Silicon (BSES) mg/kg	160						
ECEC me%	3.47						
Aluminium saturation %	1.1						
Sodium % of cations (ESP)	2.0						
Phos. Buffer Index (PBI)	77						
Colour (Munsell)	Greyish brown						
Texture	Sandy Clay Loam						

Figure 4.2 Example of a soil test report from a commercial laboratory.

Appropriate nutrient inputs for this soil test report are calculated as follows (using the guidelines in Chapter 2):

Nitrogen

N requirement is **130 kg N/ha** because the N mineralisation index is MODERATE due to an Org C (%) value of 1.3%. This requirement is appropriate for replant cane and ratoon cane after replant, but is modified according to the effect of fallow management or the use of ameliorants such as mill mud and/or mill ash. If, for example, the plant cane followed a grass/bare/poor legume fallow, the plant crop N requirement is **110 kg N/ha.**

Phosphorus

0 kg P/ha is required for plant cane because the BSES P value is 80 mg/kg and the P sorption class is LOW as indicated by a PBI of 77. If a PBI value was not available, P sorption would have been estimated as being MODERATE using texture and % Org C. No maintenance dressings of P are required in subsequent ratoon crops in this case.
NB: As clay content is not normally reported in soil tests it is reasonable to use an approximate clay content determined from the ECEC (Table 2.6) or using the 'soil texturing' method described in Appendix 1. In this analysis, the soil texture class estimated from ECEC of 3.47 me% is 'Sand'.

Potassium

K requirement is **100 kg K/ha** because the Nitric K value is more than 0.7 me%, the texture is described as a loam (24-36 % clay) and an exchangeable K value of 0.16 me%. **100 kg K/ha** is needed for each ratoon crop.

Sulphur

S requirement is **10 kg S/ha** for the plant and all ratoon crops because the soil sulphur value is 5 mg/kg and the N mineralisation index is known to be MODERATE (as described above).

Magnesium

There is no Mg requirement for the plant and all ratoon crops because the exchangeable Mg value is 1.0 me%.

Copper and zinc

Although leaf analysis is the preferred means of determining micronutrient requirements, the soil tests indicate that no zinc and no copper are required because the values are above the critical values shown in Table 2.14.

Silicon

No silicon is required because both soil tests (BSES and $CaCl_2$) are above the respective critical values shown in Table 2.15.

Lime

No lime is required because the soil pH(water) value is above 5.5 and the exchangeable calcium value is above 1.5 me%.

A summary of the nutrient requirement for the entire crop cycle in this example (Plant crop and three successive ratoons) is as follows:

Crop	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)
Replant cane	130	0	100	10
Ratoon crops	130	0	100	10

Leaf analysis

Leaf analysis offers an appropriate means of checking on the adequacy of fertiliser recommendations and nutrient inputs to a block of sugarcane. It allows adjustment of fertiliser rates in the subsequent crop (or in the current crop if the cane was young enough at the time of sampling). It also allows possible nutrient problems associated with 'poor cane' to be identified and is an important tool for monitoring nutrient trends at different scales (cane block, farm and region). Leaf sampling instructions are supplied in Appendix 3.

Leaf analysis results are interpreted according to the third leaf critical values shown in Table 4.1. It should be noted that third leaf N values decrease as the season progresses.

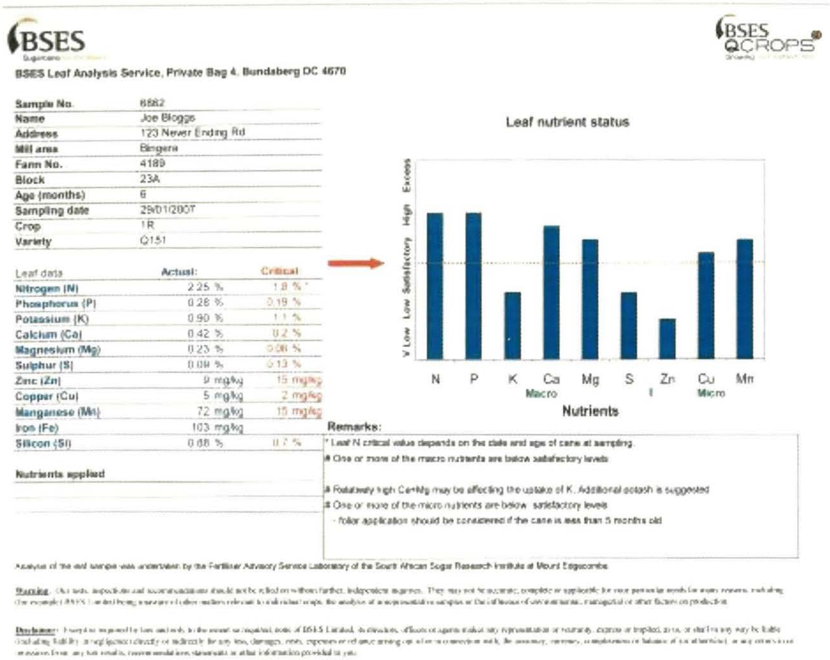
Table 4.1 - Third leaf nutrient critical values for sugarcane

Nutrient	Month of sampling	Third leaf critical nutrient value (%)
N	Nov - mid Jan	1.9 %
	Mid Jan - Feb	1.8 %
	Mar - May	1.7 %
P	Nov - May	0.19 %
K		1.1 %
Ca		0.2 %
Mg		0.08 %
S		0.13 %
Cu		2 mg/kg
Zn		15 mg/kg
Mn		15 mg/kg
Si		0.7 %

Leaf analysis data and third leaf critical values are incorporated in reports from the BSES Leaf Analysis Service. The reports include a bar-graph representation of values to assist growers in identifying the nutrient status of their crop. An example of a leaf analysis report is shown in Figure 4.3. Apart from showing the actual analysis data and appropriate critical values for the full range of nutrients, the bar graphs provide an easy to understand interpretation, with the red dotted line indicating satisfactory levels. Statements below the bar-graph add to this interpretation.

In this example, the leaf analysis results are alerting Mr Joe Bloggs to the following:

- The third leaf N value is high. This reflects the relatively high N fertiliser application rate (170 kg N /ha). Less N fertiliser should be applied next season.
- The third leaf P, Ca, Mg, Cu and Mn values are all satisfactory.
- The third leaf K value is low and reflects the relatively low K fertiliser rate (60 kg K /ha). Joe should consider applying additional K next season.
- The third leaf S value is slightly low. DAP (diammonium phosphate) which is currently used at planting does not contain sulphur. Joe should apply fertiliser mixtures that contain some sulphur in order to replace the S removed by the crop.
- The third leaf Zn value is very low. Had the cane been younger at the time of sampling, Joe could possibly have considered a foliar application of 1% zinc sulphate solution (300 litres/ha). Next season he should consider either applying zinc fertiliser (to the soil) or a foliar application of zinc sulphate when the cane is about 3 months old.



BSES Leaf Analysis Service, Private Bag 4, Bundaberg DC 4670

Sample No.	6882
Name	Joe Bloggs
Address	123 Never Ending Rd
Mill area	Bingera
Farm No.	4189
Block	23A
Age (months)	6
Sampling date	29/01/2007
Crop	1R
Variety	Q151

Leaf data	Actual:	Critical
Nitrogen (N)	2.25 %	1.8 % *
Phosphorus (P)	0.28 %	0.19 %
Potassium (K)	0.90 %	1.1 %
Calcium (Ca)	0.42 %	0.2 %
Magnesium (Mg)	0.23 %	0.08 %
Sulphur (S)	0.08 %	0.13 %
Zinc (Zn)	9 mg/kg	15 mg/kg
Copper (Cu)	5 mg/kg	2 mg/kg
Manganese (Mn)	72 mg/kg	15 mg/kg
Iron (Fe)	103 mg/kg	
Silicon (Si)	0.68 %	0.7 %

Nutrients applied

Remarks:

* Leaf N critical value depends on the date and age of cane at sampling.

\# One or more of the macro nutrients are below satisfactory levels

\# Relatively high Ca+Mg may be affecting the uptake of K. Additional potash is suggested

\# One or more of the micro nutrients are below satisfactory levels

- foliar application should be considered if the cane is less than 5 months old

Figure 4.3 Example of a leaf analysis report

Juice analysis

Juice analysis has been proposed as a means of identifying nutrient imbalances in sugarcane. For instance, it has been reported that amino N levels in cane juice are indicative of high N application rates and also contribute to increased colour in sugar. However, the absence of critical values for N and other nutrients has not enabled this technique to be used for developing routine fertiliser recommendations.

Integrated nutrient management

Analytical results for a single soil or leaf sample are of limited value. Of much more benefit is the concept of integrated nutrient management which includes the use of a range of different activities for determining nutrient inputs to a particular cane block. This integrated nutrient management package is known as the SIX EASY STEPS and consists of:

1. Knowing which soils occur in each block of your farm.
2. Understanding the properties of each soil and the nutrient processes and loss pathways likely to occur in each soil.
3. Regular soil testing (blocks should be sampled before every crop cycle).
4. Developing a plan of fertiliser applications for each block covering a whole crop cycle (a plant crop and at least three successive ratoons). This can be achieved using knowledge of the nutrient requirement of each soil and implementing soil/site specific fertiliser recommendations.
5. Checking on the adequacy of fertiliser recommendations (leaf analysis, strip trials, etc) to enable nutrient management plans to be modified if necessary.
6. Maintaining a good record keeping system to enable informed decisions to be made based on block histories and longer-term nutrient management strategies.

Implementation of this system on-farm will lead to best practice nutrient management and sustainable sugarcane production.

Concluding remarks

Soils are complex physical, chemical and biological systems which store and release nutrients for crop growth and are not simply for holding up plants. The amount and rate of release of nutrients from different soils and the reactions between soils and fertilisers need to be taken into account when developing nutrient guidelines. This complexity is appreciated by cane growers in the Plane Creek district who have an excellent understanding of the different soil types occurring on their farms and recognise that different management practices are appropriate for different soils. The information presented in this booklet is intended to reinforce this local soil knowledge and provides an easily understood system for soil and nutrient management. It focuses much more than current systems on the chemical, physical and biological properties of different soils.

Our new philosophy focuses on the management of different soils to enhance their ability to store and supply a wide range of nutrients to the crop. It emphasises the importance of improving levels of soil organic matter and has the long term goal of improving soil fertility through the enhancement of natural soil processes and nutrient cycles. It differs from current approaches in the following ways:

- Lime is recommended for the amelioration of soil acidity even though many soils are well supplied with calcium.
- Our nutrient management guidelines take into account the release of N, P and S in the soil through the mineralisation of soil organic matter. Our N guidelines in particular are lower than previous recommendations. This is particularly important given current concerns regarding elevated levels of nitrate in the waters of the Great Barrier Reef lagoon.
- We recognise that soils differ in their capacity to sorb added P fertiliser and render it less available to sugarcane crops. We therefore interpret the standard BSES P test somewhat differently for different soils.
- Our K guidelines are broadly similar to previous recommendations but take into account differences in soil texture. They are higher than previous K application rates and recognise the low exchangeable K levels in nearly all Plane Creek soils. They can be justified by the fact that we have not been replacing crop removal of K and have thus been exploiting soil K reserves.

We hope that this booklet will improve the local awareness and understanding of different soils and how they can be managed for sustainable sugarcane production. Whilst growers can use the management guidelines directly for their different soils, the booklet also explains the way in which the nutrient management guidelines have been derived so that growers can make informed decisions on how to manage their soils. It also provides guidelines for interpreting soil and leaf analyses. We hope this will encourage growers to make greater use of these important nutrient management tools.

APPENDIX 1

How to determine soil texture

The texture of a soil is defined as the relative proportions of sand, silt and clay particles in the soil. In the laboratory, the particle size distribution is determined by measuring the percentages of each of these particles in a particular soil. In the field, the field texture grade of a soil (sand, sandy loam, loam, clay loam, silty clay loam, clay, etc) can be estimated by observing the behaviour of a small handful of soil, moistened with enough water to ensure that a ball (bolus) can be formed with kneading and then pressed between thumb and forefinger to produce a ribbon. The texture is determined by noting certain characteristics of the moistened soil and comparing the length of this ribbon (mm) with the ranges indicated in the following table.

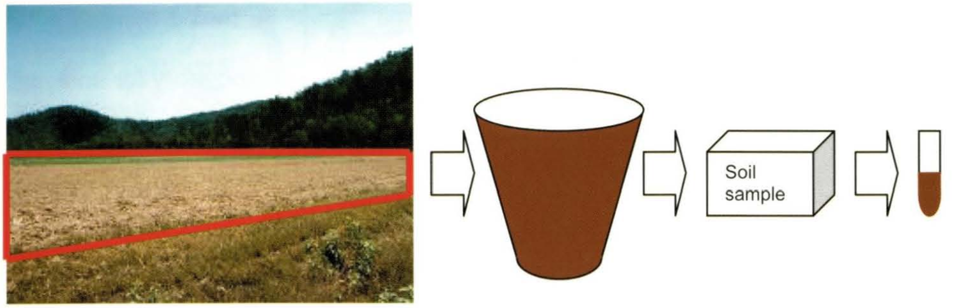
Forming the ball (bolus) of soil and pressing it into a ribbon

Table 1: Simplified guide to determining soil texture

Characteristics of the soil bolus and ribbon	Length of the ribbon (mm)	Textural grade	Approximate clay %
Sandy feel, no coherence with single grains sticking to fingers	Nil	Sand	0 - 10
Sandy feel, slight coherence, with discolouration of fingers	5-15	Loamy sand	5 - 15
Sandy feel, slight coherence	15-25	Sandy loam	10 - 20
Spongy, greasy feel, with coherence, but no obvious sandiness of silkiness	25	Loam	10 - 24
Smooth, silky feel, with distinct coherence	25	Silt loam	10 - 24
Sandy feel but with distinct coherence	25-40	Sandy clay loam	20 - 30
Smooth feel with strong coherence and no obvious sand grains	40-50	Clay loam	25 - 40
Smooth, silky feel with distinct coherence	40-50	Silty clay loam	25 - 40
Easily moulded with sandy feel	50-75	Sandy clay	25 - 50
Easily moulded with smooth and silky feel	50-75	Light clay / silty clay	35 - 45
Easily moulded (like plasticine), smooth feel, but with resistance to shearing	+75	Medium / heavy clay	> 45

How to take a soil sample

Soil tests in the laboratory are carried out on a 10 g sample which is taken from about 500 g of soil submitted to the laboratory. Usually this 500 g sample is a sub-sample of about 10 kg of soil which ideally should be sampled from a block of cane (average 2 hectare area) which contains about 6,000 tonnes of soil in the plough layer.

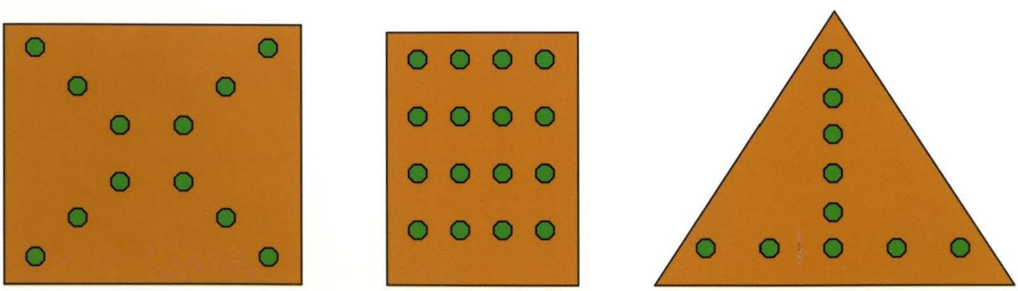


Soil: 6,000 tonnes 5-10 kg 500 g 10 g

The 10 grams of soil analysed in the laboratory is a sub-sample of the soil sample collected in the field and represents around 1.6 parts per billion. In view of this it is extremely important that a soil sample is representative of the volume of soil from which it is collected. This is achieved by collecting adequate soil from the block being sampled using a standard procedure.

Soil sampling procedure

- Determine the area that is to be sampled. Ensure that the area (or block) being sampled does not exceed 2 or 3 hectares and that it is relatively uniform in soil type. In large blocks consider taking multiple samples and if a block consists of more than one distinct soil type sample each separately. Avoid sampling areas that differ in terms of crop growth or where large amounts of mill mud or other ameliorants have been dumped. Again, sample such areas separately if necessary.
- Sampling is traditionally undertaken using an auger (either a turning auger or a soil coring tube) to a depth of 20 cm.
- At least 10 or 12 'augerings' should be collected from the area, using a zig-zag or grid pattern. The basic principle is that more 'augerings' are better than less.



Some suggested sampling patterns within cane blocks of different shapes.

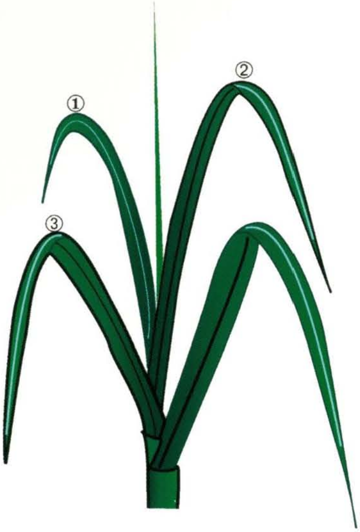
- Whilst there is some debate as to where soil samples should be taken in relation to the cane row or inter-row, we suggest that all samples be taken from the shoulder of the cane row, approximately mid-way between the centre of the cane row and the centre of the inter-row. By following this rule you will avoid sampling the highly compacted centre of the inter-space where there are likely to be fewer roots. You will also avoid sampling the centre of the cane row where you are likely to encounter the cane stool and/or residual plant cane fertiliser.
- If possible, take soil samples in the last ratoon crop just after harvest. You should then have sufficient time to apply lime and/or soil ameliorants to the fallow, well before planting.
- Make sure you exclude all plant material such as cane leaves and trash, pieces of stool, roots, etc from the soil sample. Otherwise, the soil organic carbon % may be higher than expected.
- All sub-samples should be collected in a good quality plastic bag or a clean plastic bucket to form a single composite sample. After collection, the soil should be mixed thoroughly to ensure uniformity of the sample.
- Preferably the complete sample should be dispatched to a reputable laboratory for analysis. If the sample is too cumbersome, however, a portion (500 g - 1 kg) should be sub-sampled for analysis. Ideally this should occur after air-drying and initial sieving. However, such facilities are not always available. Assistance may be obtained from BSES.
- Supply as many details as possible on a label and on the sample bag itself to ensure that the sample can be easily identified, and that meaningful interpretation of the results is possible.

Remember: Care should be taken to ensure that the sample is not contaminated. Cleanliness is most important. Always ensure that the auger is cleaned between sampling different blocks, that any buckets used are clean and that new plastic bags are used. Do not use a soil sampler or shovel made from galvanised iron or a bucket with a galvanised handle if the soil is to be hand-mixed, otherwise zinc contamination could occur.

APPENDIX 3

How to take a leaf sample

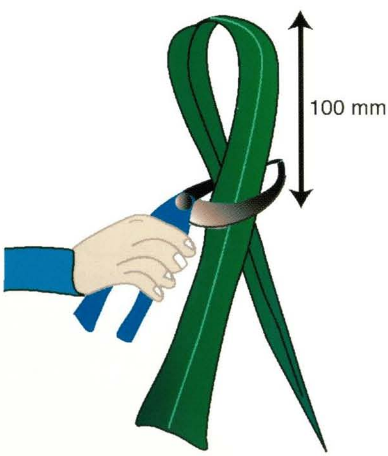
Step 1

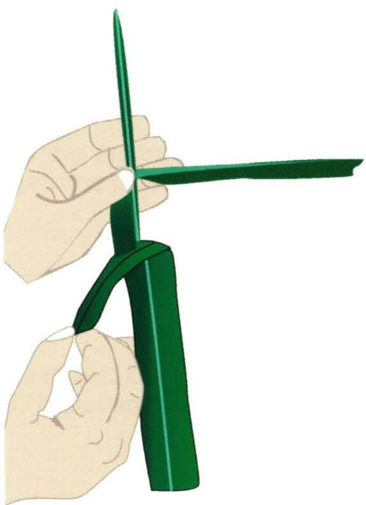


- Select leaves from stalks of average height.
- Sample the third leaf from the top of the stalk (as shown on the diagram). Counting from the top of the plant, the first leaf is the one that is more than half-unrolled. The third leaf usually corresponds to the top visible dewlap.
- Collect 30 - 40 leaves at random from across the entire block of sugarcane being sampled.

Step 2

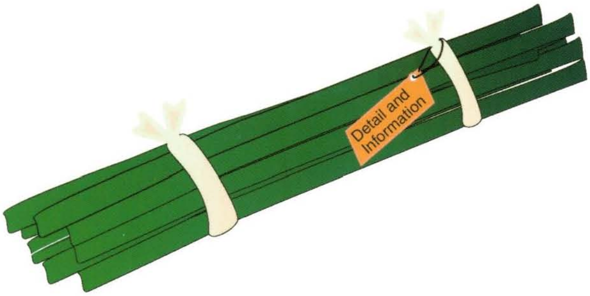
- Fold the leaves in half (top to base) and cut a 100-200 mm length from these folded leaves (giving a total 200-300 mm section of each leaf). Retain these middle 200-300 mm sections of the leaf blades and discard the remaining top and bottom sections.
- Strip out and discard the midrib from each 200-300 mm section.





Step 3

- Bundle the leaf strips together and attach a completed BSES Leaf Analysis label.



- Place the sample in a cool environment (polystyrene cooler) until it can be dried in an oven (at about 60^0C) or in a dry well-ventilated area.
- Once the sample is dry, place it in a clean paper bag or envelope, and send it to:

BSES Leaf Analysis Service
Ashfield Road / Private Bag 4
Bundaberg DC Qld 4670

To ensure meaningful interpretation of the analysis results, make sure that the following guidelines are adhered to:

- Cane is sampled during the prescribed leaf-sampling season (December to April).
- Cane is the correct age (3-7 months) at the time of sampling.
- Cane has been growing vigorously during the month prior to sampling.
- Cane is not affected by moisture stress at the time of sampling.
- Cane is also unaffected by any other factors, such as disease, insect damage, etc.
- At least 6 weeks has passed since fertiliser applications.

It is important that leaves are sampled correctly and that all the details requested on the BSES Leaf Analysis Service labels be supplied as accurately as possible. This will enable meaningful interpretation of the analysis results.

Labels and brown paper packets are available from BSES Experiment Stations and Extension Offices. If you would like to make use of this facility or get more information regarding leaf analysis, please contact you local BSES Extension Officer.

FURTHER READING

The material covered in this booklet includes information drawn from various sources. This expertise and knowledge is gratefully acknowledged, particularly in relation to the following publications and/or reports. The list also provides details of some further reading options.

Aitken RL. 2002. Control of acidity and soil acidification. In Bruce RC (ed). *Sustainable nutrient management in sugarcane production: Short Course*. CRC for Sustainable Sugar Production, Townsville, pp. 59-62.

Bell MJ, Halpin NV, Garside AL, Stirling, GR, Moody, PW and Robotham BG. 2003. Evaluating combinations of fallow management, controlled-traffic and tillage options in prototype sugarcane systems at Bundaberg. *Proc. Aust. Soc. Sugar Cane Technol.*, 25: (CD-ROM)

Berthelsen S, Noble AD and Garside AL. 1999. An assessment of soil and plant silicon levels in north Queensland. *Proc. Aust. Soc. Sugar Cane Technol.* 21: 92-100.

Bramley RGV and Wood AW. 2000. Risk assessment of phosphorus (P) loss and guidelines for P use in lower Herbert soils. *Final Report, SRDC, Project CLW010.*

Bruce RC (ed). 2000. Sustainable Nutrient Management in Sugarcane Production. *CRC for Sustainable Sugar Production*, Townsville.

Bruce RC (ed). 2002. Managing Soils, Nutrients and the Environment for Sustainable Sugar Production. *CRC for Sustainable Sugar Production*, Townsville.

Burkitt LL, Moody PW, Gourley CJP and Hannah MC. 2000. A simple phosphorus buffering index for Australian soils. *Australian Journal of Soil Research* 40, 497 - 513.

Calcino DV. 1994. Australian Sugarcane Nutritional Manual. BSES/SRDC, Indooroopilly.

Calcino DV, Kingston G and Haysom MBC. 2000. Nutrition of the plant. In: Hogarth DM and Allsopp PG (eds). *Manual of Cane Growing*. Bureau of Sugar Experiment Stations, Indooroopilly, pp 153-193.

Garside AL and Bell MJ. 2001. Fallow legumes in the Australian sugar industry: Review of recent research findings and implications for the sugarcane production system. *Proc. Aust. Soc. Sugar Cane Technol.* 23: 230-235.

Hogarth DM and Allsopp PG (eds). 2000. Manual of Cane Growing. Bureau of Sugar Experiment Stations, Indooroopilly.

Muller PG. 2002. Assessment of Mackay and Sarina district soils for spray and furrow irrigation of sugarcane. *Technical Publication QNRM 02077*, Department of Natural Resources and Mines, Coorparoo.

Nelson PN. 2001. Diagnosis and Management of Sodic Soils under Sugarcane. CRC for Sustainable Sugar Production, *Technical Publication*, Townsville.

Schroeder BL, Hubert JW, Hubert C, Hubert FG, Panitz JH, Wood AW and Moody PW. 2007. Recognising differences in soil type to guide nutrient inputs on-farm - A case study from Bundaberg. *Proc. Aust. Soc. Sugar Cane Technol.* 29: 138-148.

Schroeder BL, Moody PW and Wood AW. 2003. Improved nutrient management in the Australian sugar industry. *Final Report, SRDC, Project BSS232.*

Schroeder BL, Panitz JH, Wood AW, Moody PW and Salter B. 2007. Soil-Specific Nutrient Management Guidelines for Sugarcane Production in the Bundaberg District. *Technical Publication TE07004*, BSES Limited, Indooroopilly.

Schroeder BL and Wood AW. 2001. Assessment of the nitrogen mineralising potential of soils in two different landscapes in the Australian sugar industry - implications for N fertiliser management. *Proc. Aust. Soc. Sugar Cane Technol.* 23: 281-288.

Schroeder BL, Wood AW, Hardy S, Moody PW and Panitz JH. 2006. Soil-Specific Nutrient Management Guidelines for Sugarcane Production in the Proserpine District. *Technical Publication TE04003*, BSES Limited, Indooroopilly.

Schroeder BL, Wood AW, Moody PW, Bell MJ and Garside AJ. 2005. Nitrogen fertiliser guidelines in perspective. *Proc. Aust. Soc. Sugar Cane Technol.* 27: 291-304.

Schroeder BL, Wood AW, Moody PW, Panitz JH, Agnew JR, Sluggett RJ and Salter B. 2006. Delivering nutrient management guidelines to growers in the central region of the Australian sugar industry. *Proc. Aust. Soc. Sugar Cane Technol.* 28: 142-154.

Schroeder BL, Wood AW, Moody PW, Stewart RL, Panitz JH and Benn J. 2007. Soil-specific Nutrient Management Guidelines for Sugarcane Production in the Johnstone Catchment. *Technical Publication TE07001*, BSES Limited, Indooroopilly.

White RE. 1997. Principles and Practices of Soil Science. 3rd Edition. Blackwell Science Ltd, Oxford.

Wills AK and Baker DE. 1988. Plane Creek Sugar Cane Land Suitability Study. *Land Resource Bulletin QV88003,* Department of Primary Industries, Brisbane.

Wood AW, Noble AD and Bramley RGV. 2002. Improving the environment for sugarcane growth through the amelioration of soil acidity. *Final Report, SRDC, Project CSR024.*

Wood AW and Schroeder BL. 2004. Potassium: A critical role in sugarcane production, particularly in drought conditions. *Proc. Aust. Soc. Sugar Cane Technol.* 26: CD-ROM.

Wood AW, Schroeder BL and Stewart RL. 2003. Soil Specific Management Guidelines for Sugarcane Production. *Soil Reference Booklet for the Herbert District.* CRC for Sustainable Sugar Production Technical Publication, Townsville.

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